<u>Public Comments Received on 2008 Draft 303(d) List</u>

On February 23, 2008, the New Hampshire Department of Environmental Services (DES) released the draft Section 303(d) List of impaired waters for public comment. Downloadable copies of the draft list were made available on the DES website for review (www.des.state.nh.us/wmb/swqa/).

The public comment period ended on March 23, 2008. The following represents the full text of the public comments received during this period.

Two sets of comments were submitted in response to the departments February 23, 2008

1. Donna Hanscom, Assistant Public Works Director/Laboratory Manager, City of Keene, New Hampshire (pages 2-6)

2. Thomas F. Irwin, Senior Attorney, Conservation Law Foundation (pages 7-110)

The comments, as submitted, are provided below.

City of Keene, New Hampshire

From: Donna Hanscom [dhanscom@ci.keene.nh.us] Sent: Fri 3/21/2008 1:34 PM
To: 303d Comment
Cc: Eric Swope; Comstock, Gregg; Foss, Margaret; John Gall
Subject: Assessment unit NHRIV802010301-11
Attachments: DO data.msg; RE Supplemental information needed for data you provided to DES.msg

Ken,

I have attached the email that I sent to Gregg Comstock back in January 2008 -- the associated QC and data were submitted to Peg Foss later that month (also attached). We did not receive any feedback on the submission, and request that this information be considered during the comment period of the 303D list to remove AU NHRIV802010301-11 from the impaired list. This spreadsheet contains support for the attainment of the above referenced river section for dissolved oxygen. Specifically, it shows that in the summer of 2007, during a river flow comparable to the river flow at the time of DES's non-attainment data collection, the DO met dissolved oxygen water quality criteria. It also demonstrates a lower total phosphorus concentration in the river. The cause of the lower phosphorus concentration is presumably the lower concentration of phosphorus discharged by the Keene WWTP -- data on file with DES and EPA as part of the DMR reporting process and NPDES permitting process.

This data is directly relevant to reversing the non-attainment label for this river section, especially as it is described as category 5-M -- marginal impairment as described in the CALM.

Associated QC is included. The data was collected using Hydrolab equipment by Eric Swope, Industrial Pretreatment Coordinator for the City of Keene.

If you need additional information, please contact me.

Donna

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Donna Hanscom
Assistant Public Works Director/Laboratory Manager
City of Keene, New Hampshire
Phone: 603-357-9836, extension 6501
Fax: 603-357-9854
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From: Donna Hanscom [dhanscom@ci.keene.nh.us] Sent: Tue 1/22/2008 10:22 AM
To: Comstock, Gregg
Cc: Eric Swope
Subject: DO data
Attachments: 8-30-07 summary to DES.xls (48 KB)

Hi Gregg,

Attached is the Ashuelot River DO data from August 30, 2007. I've also included the upstream DO for the same day, and the WWTP data you requested on separate worksheets. We didn't have WWTP total P for that day, but I included the data for a couple days later and two weeks before showing a pretty consistent 1 mg/L. I'll see you later today, let me know if you need additional information to consider this for the 303 list compilation. You can also contact Eric Swope (357-9836, ext 6504) with questions, he was the one who deployed the hydrolabs. The file I sent you in November was called "8-28-07 summary to DES" -- but the data was really from 8-30, it's the same downstream data that's contained in this one.

Donna
<<8-30-07 summary to DES.xls>>

From: Donna Hanscom [dhanscom@ci.keene.nh.us] Sent: Thu 1/31/2008 1:14 PM
To: Eric Swope
Cc:
Subject: RE: Supplemental information needed for data you provided to DES

From: Eric Swope
Sent: Thursday, January 31, 2008 10:10 AM
To: 'Foss, Margaret'
Cc: Donna Hanscom; Aaron Costa
Subject: RE: Supplemental information needed for data you provided to DES

Hello Peg,

I think I have answered all of your questions/concerns with the attached info and the comments below. Please send an email or give a call to verify that you have received this.

1. The "Keene WWTP data" referenced in your first question is data collected form the WWTP's effluent.
2. Total Phosphorus analysis was completed by Eastern Analytical, Inc. (EAI) using Method 365.3. EAI's SOP, results, and QA/QC information are attached. cBOD results are an average between results obtained by Keene City Lab and EAI using Method 5210B. Results, QA/QC information, and KCL Method SOP is attached. Ammonia results
3. The continuous DO information was collected using the City of Keene's Hydrolab Mini-Sondes, Series 4a. The "upstream" probe was deployed approximately 150' upstream of the Keene WWTP outfall. The "downstream " probe was deployed approximately 150' downstream of the WWTP outfall. Downstream deployments later in the summer and fall were several hundred feet further downstream, approximately 150' upstream of the South Branch outfall into the Ashuelot. Both meters were set to collect DO readings every 30 minutes. Sensor warm-upset for 2 minutes and circulator warm-up set for 1 minute. The KCL field DO Meter was also calibrated (SOP and DO Calibration Log Sheet are attached), and readings of DI water in a bucket at KCL were compared for accuracy both pre- and post-deployment (results are in the DO data spreadsheet submitted to NHDES).
4. I think this was answered in the above section.

Please contact me with any questions or if you need any additional information.

Thank you,

Eric

Eric Swope
Industrial Pretreatment Coordinator

Mailing Address:
Keene Wastewater Treatment Plant
350 Marlboro Street
Keene, NH 03431
Physical Address:
Keene Wastewater Treatment Plant
420 Airport Road
Swanzey, NH 03446
Phone: (603) 357-9836, ext. 6504
Fax: (603) 357-9854

Log File Name : ARUP083007
Setup Date (MMDDYY) : 083007
Setup Time (HHMMSS) : 141654
Deployed in river about 150' upstream of WWTP outfall on 8/30/07 at about 15:25.
removed from river on 8/31/07 at about 13:30
QC comparison with City lab meter YSI-52

Pre-Deployment			Post-Deployment		
YSI-52	Mini-sonde #2		YSI-52	Mini-sonde #2	
7.6	7.4	mg/l	7.9	7.1	mg/l
		% sat	92	82	% sat

Date MMDDYY	Time HHMMSS	IBatt Volts	Circ Status	IBatt %Left	Temp øC		DO% Sat	DO mg/l
Parameter setup or calibration changed at 083007 142022								
83007	153000	5.1	1	55	22.93		96.3	8.32
83007	160000	5.3	1	62	23.01		94.2	8.12
83007	163000	5.3	1	62	23.08		94.6	8.14
83007	170000	5.3	1	62	23.06		95	8.18
83007	173000	5.3	1	62	23.02		94.5	8.15
83007	180000	5.3	1	62	22.92		93.3	8.06
83007	183000	5.3	1	62	22.8		92.1	7.98
83007	190000	5.3	1	62	22.69		90.6	7.86
83007	193000	5.3	1	62	22.61		88.7	7.71
83007	200000	5.3	1	62	22.51		87.9	7.65
83007	203000	5.3	1	62	22.46		86.8	7.56
83007	210000	5.3	1	62	22.4		85.8	7.48
83007	213000	5.3	1	58	22.35		84.5	7.37
83007	220000	5.3	1	62	22.3		84	7.34
83007	223000	5.3	1	62	22.24		83.3	7.29
83007	230000	5.3	1	58	22.18		82.9	7.26
83007	233000	5.3	1	58	22.12		82.3	7.22
83107	0	5.2	1	62	22.06		81.6	7.17
83107	3000	5.3	1	58	22		81.1	7.13
83107	10000	5.2	1	62	21.94		80.7	7.1
83107	13000	5.2	1	58	21.88		80.1	7.06
83107	20000	5.2	1	62	21.83		80	7.05
83107	23000	5.2	1	58	21.78		79.2	6.99
83107	30000	5.3	1	58	21.73		79.2	7
83107	33000	5.2	1	58	21.67		78.6	6.95
83107	40000	5.2	1	58	21.62		78	6.9
83107	43000	5.2	1	58	21.58		77.7	6.89
83107	50000	5.2	1	58	21.53		76.4	6.78
83107	53000	5.2	1	58	21.5		75.9	6.74
83107	60000	5.2	1	62	21.47		75.8	6.73
83107	63000	5.2	1	58	21.44		75.4	6.7
83107	70000	5.2	1	58	21.4		74.4	6.61
83107	73000	5.2	1	55	21.41		75.1	6.68
83107	80000	5.1	1	58	21.42		74.7	6.64
83107	83000	5.2	1	58	21.41		75.3	6.69
83107	90000	5.2	1	55	21.43		75.7	6.73
83107	93000	5.2	1	58	21.48		76.7	6.81
83107	100000	5.2	1	58	21.53		77.6	6.89
83107	103000	5.2	1	58	21.57		78.8	6.98
83107	110000	5.2	1	58	21.64		80	7.08
83107	113000	5.1	1	58	21.78		82.6	7.29
83107	120000	5.2	1	58	21.96		83.8	7.37
83107	123000	5.1	1	58	22.2		85	7.44
83107	130000	5.2	1	55	22.28		85.5	7.47
Recovery finished at 083107 151655								

Log File Name : ARDOWN083007								
Setup Date (MMDDYY) : 083007								
Setup Time (HHMMSS) : 135454								
Deployed in river about 150' downstream of WWTP outfall on 8/30/07 at about 15:35. Same location as used in July for temp readings.								
Removed from river on 8/31/07 at about 13:40.								
QC comparison with City lab meter YSI-52								
Pre-Deployment			Post-deployment					
YSI-52	Mini-sonde # 3		YSI-52	Mini-sonde # 3				
7.6	7.5	mg/l	7.9	7.1	mg/l			
87.1	85.8	% sat						
Date	Time	IBatt	Circ	IBatt	Temp		DO%	DO
MMDDYY	HHMMSS	Volts	Status	%Left	øC		Sat	mg/l
Parameter setup or calibration changed at 083007 145251								
83007	160000	5.3	1	62	22.78		89.3	7.73
83007	163000	5.2	1	62	22.84		90	7.78
83007	170000	5.3	1	62	22.86		90.1	7.79
83007	173000	5.3	1	58	22.85		89.8	7.76
83007	180000	5.3	1	62	22.8		89.5	7.75
83007	183000	5.2	1	58	22.76		88.7	7.68
83007	190000	5.2	1	58	22.65		88.9	7.72
83007	193000	5.2	1	55	22.6		88.2	7.67
83007	200000	5.2	1	55	22.49		86.4	7.52
83007	203000	5.2	1	58	22.37		86.2	7.52
83007	210000	5.2	1	58	22.29		84.7	7.4
83007	213000	5.2	1	55	22.23		84.6	7.41
83007	220000	5.2	1	58	22.18		83.3	7.3
83007	223000	5.1	1	55	22.15		82.3	7.21
83007	230000	5.1	1	55	22.11		82.5	7.23
83007	233000	5.2	1	55	22.06		82.1	7.21
83107	0	5.1	1	58	22		81.5	7.17
83107	3000	5.1	1	55	21.94		81.6	7.18
83107	10000	5.1	1	55	21.88		80	7.05
83107	13000	5.2	1	58	21.83		79.9	7.04
83107	20000	5.1	1	58	21.76		78.9	6.97
83107	23000	5.1	1	51	21.72		78.2	6.91
83107	30000	5.1	1	55	21.67		79	6.98
83107	33000	5	1	55	21.58		76.9	6.81
83107	40000	5.1	1	55	21.56		78.3	6.94
83107	43000	5.1	1	55	21.51		77.9	6.91
83107	50000	5	1	55	21.47		77.4	6.87
83107	53000	5.1	1	51	21.42		76.8	6.83
83107	60000	5	1	55	21.39		76.9	6.83
83107	63000	5.1	1	51	21.35		76.5	6.81
83107	70000	5.1	1	55	21.33		76.1	6.78
83107	73000	5	1	55	21.3		75.4	6.72
83107	80000	5.1	1	51	21.29		75.4	6.72
83107	83000	5.1	1	55	21.28		75.4	6.72
83107	90000	5.1	1	51	21.25		74.7	6.66
83107	93000	5.1	1	55	21.27		75.1	6.69
83107	100000	5	1	51	21.34		77.3	6.88
83107	103000	5	1	51	21.38		78	6.94
83107	110000	5	1	51	21.45		79.2	7.03
83107	113000	5.1	1	55	21.53		80.3	7.12
83107	120000	5	1	51	21.73		82.9	7.32
83107	123000	5.1	1	51	21.9		84.4	7.43
83107	130000	5.1	1	51	22.07		85.8	7.53
83107	133000	5.1	1	55	22.23		87.2	7.63
Power loss from 083107 135755 to 083107 135806				Removed sonde at about 13:40				
Late probe turn on at 083107 135806								

CONSERVATION LAW FOUNDATION

March 24, 2008

Hand-Delivered
Mr. Ken Edwardson
2008, 303(d) Comments
N.H. Department of Environmental Services
Watershed Management Bureau
29 Hazen Drive, P.O. Box 95
Concord, NH 03302-0095

MAR 24 2008

Via U.S. Mail
Mr. Alfred Basile
New Hampshire TMDL Coordinator
Water Quality Branch (CWQ)
U.S. Environmental Protection Agency, Region 1
One Congress Street
Boston, MA 02114-2023

Re: Comments on State of New Hampshire Draft 2008 Section 303(d) List

Dear Messrs. Edwardson and Basile:

Please find enclosed the Conservation Law Foundation's comments on the State's Draft Section 303(d) List. Please note that I am submitting these comments in accordance with my March 18 conversation with Mr. Edwardson, at which time I was advised that because the publicized deadline of March 23, 2008 is a Sunday, comments can be submitted by close-of-business on March 24, 2008.

Should you have any questions, please do not hesitate to contact me.

Very truly yours,

Thomas F. Irwin
Senior Attorney

cc: Mr. Steve Silva, Chief, Water Quality Branch, EPA New England

Encls.: Comments on State's Draft Section 303(d) List and appended Attachments A through H.

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Comments of the Conservation Law Foundation

Submitted To

New Hampshire Department of Environmental Services

and

U.S. Environmental Protection Agency, Region I

Regarding

State of New Hampshire Draft 2008 Section 303(d) Surface Water Quality List NHDES-R-WD-08-3 (February 2008)

The Conservation Law Foundation ("CLF") appreciates the opportunity to provide these comments on the State of New Hampshire Draft 2008 Section 303(d) Surface Water Quality List ("Draft 303(d) List" or "Draft List"). CLF is a member-supported advocacy organization that works to solve the environmental problems facing communities and natural resources in New Hampshire and throughout New England. CLF and its members have a strong interest in maintaining the health of New Hampshire's water resources. CLF has engaged in concerted, ongoing efforts to address and reduce existing threats and water quality problems facing New Hampshire's Great Bay estuary. We submit the following comments:

I. Legal Overview

Section 303(d) of the Clean Water Act and EPA's "Water Quality Planning and Management" regulations require that the State of New Hampshire ("State"), like all states, identify all waters for which technology-based effluent limitations and other pollution control requirements are insufficient to implement water quality standards. 33 U.S.C. § 1313(d)(1); 40 CFR § 130.7(b). For purposes of identifying such water quality limited segments for Section 303(d) listing, the State must determine whether waters are violating, or are expected to violate, state water quality standards (i.e., whether waters are impaired or threatened). 40 CFR § 130.7(b)(3); 40 CFR § 130.2(j).[1] In considering its water quality standards, the State must consider *narrative*, in addition to *numeric*, water quality criteria. 40 CFR § 130.7(b)(3). Thus, the State must, as a matter of law, determine whether waters are either violating, or are expected to violate, its narrative water quality standard governing "Biological and Aquatic Community Integrity," which states:

[1] The term "water quality limited segment" is defined as: "Any segment where it is known that water quality does not meet applicable water quality standards, and/or is not expected to meet applicable water quality standards, even after the application of the technology-based effluent limitations required by sections 301(b) of the [Clean Water] Act." 40 CFR 130.2(j).

(a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.

(b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.

Env-Ws 1703.19 ("BACI narrative standard"). The State also must determine whether waters are violating, or are expected to violate, narrative water quality standards pertaining to nutrients, including but not limited to Env-Ws 1703.14(b), which states: "Class B waters shall contain no phosphorous or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring."

In developing its Section 303(d) list, the State has an affirmative duty to "assemble and evaluate all existing and readily available water quality-related data and information." 40 CFR § 130.7(b)(5). Such data and information specifically includes, without limitation, data and information about "[w]aters for which water quality problems have been reported by local, state, or federal agencies; members of the public; or academic institutions." 40 CFR § 130.7(b)(5)(iii). EPA's regulations impose an affirmative obligation on the State to obtain such data and information, stating:

> These organizations and groups [i.e., agencies, members of the public, and academic institutions] should be actively solicited for research they may be conducting or reporting. For example, university researchers, the United States Department of Agriculture, the National Oceanic and Atmospheric Administration, the United States Geological Survey, and the United States Fish and Wildlife Service are good sources of field data. . . .

Id. See also Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b), and 314 of the Clean Water Act, EPA (July 29, 2005)[2] (hereinafter "2006 Guidance") at 31 (noting that "data and information should also be solicited from a wide variety of organizations and individuals, such as . . . universities and other research institutions[,] environmental consulting firms[,] National Pollutant Discharge Elimination (NPDES) permitees[, and] conservation/environmental organizations . . . ."). The affirmative nature of this obligation does not end with soliciting data and information. For example, "[i]f particular data/information referenced in the public comments are not provided, EPA expects states to make a reasonable effort to secure the data." *Id.* at 32.[3]

[2] EPA continues to rely on this guidance document, as supplemented by an October 12, 2006 EPA Memorandum regarding "Information Concerning 2008 Clean Water Act Sections 303(d), 305(b), and 314 Integrated Reporting and Listing Decisions."

[3] *See also* 2006 Guidance at 32 ("If an outside entity fails to provide necessary metadata along with submitted data and information, the state should attempt to obtain the metadata from the data-submitting organization before concluding that the data and information is of low quality, simply due to lack of metadata.").

The State's obligation to assemble data and information includes information pertaining to "observed effects" – defined as "[d]irect manifestations of an undesirable effect on waterbody conditions" – which can form the basis of a decision to identify a water body as impaired. *Id.* at 31, 68. Uncertainty regarding the *cause* of an observed effect or other condition cannot be used as grounds to exclude a water body from Section 303(d) listing as an impaired or threatened water segment. *Id.* at 60 ("*Must Category 5 include an impaired segment if the specific pollutant causing the impairment has not been identified?* Yes, if a designated use is not supported and the segment is impaired or threatened, the fact that the specific pollutant is not known does not provide a basis for excluding the segment from Category 5. These segments must be listed unless the state can demonstrate that no pollutant(s) causes or contribute to the impairment."). *See also id.* at 22, Table 3-7 ("Cause/Stressor Unknown").

II. The Biological Health And Integrity Of The Great Bay Estuary And Associated Waters Are Critically Important.

Comprised of Great Bay, Little Bay, and the Piscataqua River, and receiving freshwater flows from numerous rivers, the Great Bay estuary is a highly sensitive, critically important resource that has been recognized as an estuarine system of national significance. It is part of the National Estuarine Research Reserve and the National Estuary Program[4] and, pursuant to the latter, is the subject of ongoing management efforts by the New Hampshire Estuaries Project ("NHEP"). The Great Bay estuary also is the subject of ongoing research efforts by the University of New Hampshire's Jackson Estuarine Laboratory, as well as volunteer monitoring by Great Bay Coast Watch.

Within the Great Bay estuary, eelgrass provides an essential role that has been described as follows:

> Eelgrass (*Zostera marina*) is an essential habitat for the Great Bay Estuary (GBE) because it provides food for wintering waterfowl and habitat for juvenile fish and shellfish. Eelgrass is the basis of an estuarine food chain that supports many of the recreationally, commercially and ecologically important species in the estuary. Additionally, eelgrass filters estuarine waters, removing both nutrients and suspended sediments from the water column. Eelgrass in the Great Bay Estuary is the largest monoculture in the State of New Hampshire and is considered a vital resource to the State's marine environment.

Short, Frederick T., *Eelgrass Distribution in the Great Bay Estuary, 2005: A Final Report to the New Hampshire Estuaries Project* (July 31, 2007), appended as Attachment A, at 1. Eelgrass has been further described as "an essential habitat for the estuary, the loss of which would fundamentally alter the ecosystem of the bay." NHEP, *Environmental Indicator Report: Critical Habitats and Species* (March 2006) at 8.

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[4] The National Estuary Program is a "state grant program within the U.S. Environmental Protection Agency established to designate estuaries of national significance and to assist local stakeholders in the preparation of a *Comprehensive Conservation and Management Plan* for the designated estuaries." N.H. Estuaries Project, Management Plan (2000) at AP-7.

III. Readily Available Data And Information Pertaining To Eelgrass Declines Demonstrate That Assessment Units Within The Great Bay Estuary Are Impaired.

The Draft 303(d) List includes water bodies that are part of, and associated with, the Great Bay estuary. However, the Draft List is incomplete because it omits the following impairments which, unless specifically addressed by the State through technology-based standards and other pollution control requirements, must be added to the Final List.

A. Significant eelgrass declines in the Piscataqua River and Little Bay demonstrate that these waters are impaired.

For several years, Frederick T. Short, Ph.D., a researcher at the University of New Hampshire's Jackson Estuarine Laboratory with more than twenty years experience working on Great Bay, has monitored the spatial cover and biomass of specific eelgrass communities within the Great Bay estuary. In particular, his research demonstrates substantial declines in eelgrass biomass at two sites in the Piscataqua River where eelgrass was transplanted in 1994 ("1994 transplant sites"), three other sites in the Piscataqua River, and a site in Little Bay. An abstract discussing data for these sites collected between 2001 and 2006, and documenting site locations, is appended hereto as Attachment B. As stated in this abstract, eelgrass declines observed at these sites "suggest a reduction in the health condition of the estuary." *Id.* It explains that eelgrass in the 1994 transplant sites reached functions and values comparable to natural reference sites within a six year period, but that "data from 2001 to the present shows significant decline in plant parameters, especially eelgrass biomass, density, and leaf area index." *Id.* It further states: "Between 2005 and 2006, eelgrass biomass decline ranged from 59 to 90 percent at the [1994 transplant sites] *and reference* sites." *Id.* (emphasis added). Noting a 59 percent increase in dissolved-inorganic-nitrogen concentrations in the Great Bay estuary, it states: "The overwhelming eelgrass decline at all sites indicates that these trends are the result of an estuary-wide factor." *Id.*

More recently, Dr. Short has supplemented the above analysis with 2007 data.[5] These data demonstrate that eelgrass biomass has declined significantly between 2001 and 2007, and further confirm that these significant declines are not isolated to the 1994 transplant sites, but, rather, also occurred at naturally occurring eelgrass beds within the estuary. The data show declines to be most extreme in the Piscataqua River, with three of the five sites *devoid* of eelgrass vegetation, and with eelgrass barely surviving at the two other sites. *See* Attachment C.

The above data and information unequivocally establish that the Piscataqua River and Little Bay are violating the State's BACI narrative standard, Env-Ws 1703.19.

[5] These data, and a corresponding map, are contained in figures appended hereto as Attachment C. These figures are from an as-yet unpublished manuscript (Beem, Nora T. and Fred T. Short, "Subtidal Eelgrass Decline in the Great Bay Estuary, NH-ME").

Accordingly, unless the State demonstrates that it can and will address these violations through technology-based effluent limitations and other pollution controls, these water bodies and impairments must be added to the Final List. Although certainty regarding the *cause* of these violations is not necessary for Section 303(d) listing purposes (*see* discussion, above, at 3), readily available data and information make clear that increasing nitrogen levels are a contributing factor.[6] Accordingly, the cause of these impairments should be identified as excessive nitrogen loading, and the State should also identify these waters as violating Env-Ws 1709.14. Because the potential light attenuation impacts of total suspended solids (TSS) also may be a factor, the State should consider identifying TSS as an additional potential cause.

B. Eelgrass declines within Great Bay, particularly in light of system-wide eelgrass declines and nitrogen-loading trends, demonstrate that Great Bay is an impaired water body.

In its 2003 *State of the Estuaries* report, NHEP reported that nitrogen concentrations in Great Bay were increasing. NHEP, *State of the Estuaries, 2003* at 8. The report explained that, despite increasing nitrogen concentrations in the estuary, there had not yet been "any significant trends for the typical indicators of eutrophication: dissolved oxygen and chlorophyll-a concentrations. Therefore, the load of nitrate+nitrite to the bay appears to have not yet reached the level at which the undesirable effects of eutrophication occur." *Id.* NHEP further reported that eelgrass habitat in Great Bay had, over the prior 10 years, remained relatively constant. *Id.* at 16. In its 2006 *State of the Estuaries* report, however, NHEP reported critically important new data and information about eelgrass declines and rising nitrogen levels in the estuary. Attachment D (NHEP, *State of the Estuaries, 2006* (excerpts)). With specific regard to eelgrass, it described the following disturbing trend:

> Throughout the 1990s, the total eelgrass cover in Great Bay was relatively constant at approximately 2,000 acres. In 1988 and 1989, there was a dramatic crash of the eelgrass beds down to 300 acres (15 percent of normal levels). The cause of this crash was an infestation of a slime mold, *Labryinthula zosterae*, commonly called "wasting disease." The greatest extent of eelgrass was observed in 1996 (2,421 acres) after recovery from the wasting disease. The current (2004) extent of eelgrass in Great Bay is 2,008 acres, which is 17 percent less than the maximum extent observed in 1996.
>
> The biomass of eelgrass in Great Bay has experienced a more significant decline relative to the levels observed in 1996. Biomass is the combined weight of eelgrass plants in the bay. In 1990, 1991, and 1995, biomass was low due to wasting disease events. Superimposed on these rapid events has been a gradual, decreasing trend in eelgrass biomass that does not appear to be related to wasting

[6] *See* Attachment B. *See also* Attachment A (recommending "increase[d] efforts to lower nitrogen loading to the Great Bay Estuary with particular emphasis on Portsmouth Harbor and the Piscataqua River."). *See also* footnote 8, below, regarding nitrogen trends in Great Bay.

> disease. The current eelgrass biomass level for Great Bay is 948 metric tons, which is 41 percent lower than the biomass observed in 1996.

Id. More recent data (2005) reveal that eelgrass biomass in Great Bay has further declined to 827 metric tons,[7] meaning that eelgrass biomass decreased *48 percent* between 1996 and 2005. Even absent this more recent 2005 data, NHEP has concluded that "[t]he trend of declining eelgrass biomass in Great Bay is a concern. Eelgrass is an essential habitat for the estuary, the loss of which would fundamentally alter the ecosystem of the bay." NHEP, *Environmental Indicator Report: Critical Habitats and Species* (March 2006) at 8.

The above significant, reported declines in eelgrass biomass, particularly when coupled with data and information about increasing nitrogen concentrations in Great Bay,[8] and substantial eelgrass declines in Little Bay and the Piscataqua River,[9] establish that conditions in Great Bay are violating the State's BACI narrative standard, Env-Ws 1703.19. Accordingly, unless the State demonstrates that it can and will address this violation through technology-based effluent limitations and other pollution controls, it must add this impairment to the Final 303(d) List. Although certainty regarding the *cause* of this impairment is not necessary for Section 303(d) listing purposes (*see* discussion above, at 3), readily available data and information make clear that increasing nitrogen levels are a contributing factor.[10] *See* Attachment D, at 4 (stating that "loss of

[7] Electronic communication from P. Trowbridge, NHDES, to T. Irwin, CLF providing updated eelgrass data (March 12, 2008).

[8] According to the 2006 *State of the Estuaries* report, dissolved inorganic nitrogen concentrations "increased in Great Bay by 59 percent in the past 25 years." Attachment D, at 12. The report documented that nitrogen concentrations in Great Bay had reached the same levels that had been shown to cause negative effects in other estuaries, and noted that "changes in other parts of the ecosystem, particularly eelgrass cover and biomass, have been observed. There also have been anecdotal reports of increasing populations of nuisance macroalgae in some areas of Great Bay." *Id.* at 12. According to the report: "While precise threshold for DIN effects is not known, *it is **certain** that the estuary cannot continue to receive increasing nitrogen loads indefinitely without experiencing a lowering of water quality and ecosystem changes.*" *Id.* (emphases added). *See also* written and oral testimony of Dr. Short (Attachments E and F).

[9] *See* Attachment B, and discussion above, explaining that significant eelgrass declines in Piscataqua River and Little Bay are indicative of an "estuary-wide factor."

[10] *See* Attachment B. *See also* footnote 8, above, regarding nitrogen trends in Great Bay. In addition to the above, *see also* the written and oral testimony of Dr. Short relative to nitrogen levels in the Great Bay estuary (Attachments E and F, respectively), including Dr. Short's testimony that "the Great Bay Estuary is suffering from excess nitrogen inputs," Attachment E, and that:

> Increasing nitrogen levels in an estuary are a problem because it increases gradually and suddenly – all of the sudden you get a change in the system, a dynamic turnover in the system. And the prime example of that is Chesapeake Bay, where in the 1980s the Chesapeake Bay estuary ecosystem collapsed. It lost its eelgrass, it lost its blue crabs, its oysters, because the system was too heavily loaded with nitrogen and the system fell apart. And I'm concerned at the levels of nitrogen that we're seeing here in the Great Bay estuary.
>
> Being a professor, I brought my references. The State of New Hampshire put out the state of the estuary report in 2003 and it shows a significant increase in nitrate levels in the Great Bay estuary. And I looked up those nitrogen levels and compared them to what the levels were in Chesapeake Bay in the 1980s, at the time of the collapse, and we are as high or higher than the levels were in Chesapeake Bay, so I think that's a concern.

water clarity, disease, excess nitrogen, and nuisance macroalgae," are all factors contributing to eelgrass decline.). Accordingly, the cause of this impairment should be identified as excessive nitrogen loading, and the State should also identify this water body as violating Env-Ws 1709.14. Because the potential light attenuation impacts of TSS also may be a factor, the State should consider identifying TSS as a potential cause as well.

C. Eelgrass declines within the Squamscott, Lamprey and Oyster Rivers, particularly in light of system-wide eelgrass declines and nitrogen-loading trends, demonstrate that these waters are impaired.

According to NHEP's 2006 *Environmental Indicator Report: Critical Habitats and Species*, as supplemented by more recent data, eelgrass cover has declined substantially in the Squamscott, Lamprey and Oyster Rivers. Specifically, in 1996, there were 65 acres of eelgrass cover in the Squamscott and Lamprey Rivers, collectively, and 14 acres of eelgrass in the Oyster River. NHEP, *Environmental Indicator Report: Critical Habitats and Species* (March 2006) at 9, Table 4. In 2005, the acreage of eelgrass cover declined to a mere 22 acres in the Squamscott and Lamprey Rivers (collectively), and only two acres in the Oyster River.[11] Thus, compared to 1996 data, eelgrass cover in the Squamscott/Lamprey Rivers, and the Oyster River, declined an incredible 66 and 86 percent, respectively. These significant declines are evidence that these waters are violating the State's BACI narrative standard. Therefore, unless the State demonstrates that it can and will address these violations through technology-based effluent limitations and other pollution controls, it must add these impairments to its Final 303(d) List. For the reasons discussed above, the State should identify nitrogen, and possibly TSS, as the cause of these impairments, and should further identify these waters as violating Env-Ws 1703.14.

IV. Readily Available Data And Information Pertaining To Chlorophyll a And Dissolved Oxygen Demonstrate That Certain Water Bodies Within The Great Bay Estuary Are Impaired.

According to a State of New Hampshire Inter-Department Communication included in the State's Section 305(b) report as Appendix 22, probabilistic assessments of New Hampshire estuarine waters resulted in findings that dissolved oxygen violations occurred in the lower Piscataqua River, and that high chlorophyll-a concentrations occurred in the Lamprey and Winnicut Rivers. State of NH Inter-Department Communication from P. Trowbridge to G. Comstock (March 6, 2006) at 4, 5. The Draft List fails to list these impairments. Unless the State demonstrates that it can and will

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Attachment F, at 45. *See also* Attachment G (Lee, Kun-Seop *et al.*, "Development of a nutrient pollution indicator using the seagrass, *Zostera marina*, along nutrient gradients in three New England estuaries," Aquatic Botany, Vol. 78 (2004) 197-216; Attachment H (Project Narrative Statement Workplan submitted by NHEP and NHDES to EPA) ("Increased nitrogen concentrations . . . and declining eelgrass beds in Great Bay . . . are clear indicators of impending problems for NH's estuaries.").

[11] Electronic communication from P. Trowbridge, NHDES, to T. Irwin, CLF (March 12, 2008).

address these violations through technology-based effluent limitations and other pollution controls, it must add these impairments to its Final 303(d) List.[12]

V. Alternatively, The Above-Described Data And Information Demonstrate That Water Bodies Within The Great Bay Estuary Are Threatened.

The data and information discussed above (*see* Parts III - IV) establish that the above-mentioned waters are violating water quality standards and, therefore, are impaired. Should the State and EPA somehow conclude that the above data and information do not provide evidence of *impairment*, such data and information nonetheless establish that the waters are *threatened* (i.e., are not expected to meet applicable water quality standards), and must be designated as such.[13] The State has itself acknowledged that "[i]ncreased nitrogen concentrations . . . and declining eelgrass beds in Great Bay . . . are clear indicators of impending problems for NH's estuaries." Attachment H (Project Narrative Statement Workplan submitted by NHEP and NHDES to EPA). With specific regard to nitrogen, NHEP's 2006 *State of the Estuaries* report further states: "While a precise threshold for DIN effects is not known, *it is* ***certain*** *that the estuary cannot continue to receive increasing nitrogen loads indefinitely without experiencing a lowering of water quality and ecosystem changes.*" Attachment D, at 12. *See also* testimony of Dr. Short (footnote 10, above). The threatened (if not impaired) status of the estuary, as it relates to nitrogen inputs and nitrogen-related problems, is further bolstered by the fact that sources of nitrogen – including stormwater pollution associated with existing and future impervious cover – can only be expected to increase in the next two years.

VI. If The State Elects Not To Address The Above Impairments Through Technology-Based Effluent Limitations Or Other Pollution Controls, It Should Assign Them A High Priority On The Final 303(d) List.

If the State elects to add the above impairments to the Final List, on the grounds that it cannot specifically address them through technology-based effluent limitations or other pollution controls, it should assign a high priority to these water quality limited segments for purposes of developing and implementing total maximum daily loads (TMDLs). This high prioritization is warranted by the significant value of the Great Bay

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[12] EPA guidance emphasizes the need to coordinate, and avoid inconsistencies between, Section 303(d) and Section 305(b) assessment findings. EPA Memorandum, "Information Concerning 2008 Clean Water Act Sections 303(d), 305(b) and 314 Integrated Reporting and Listing Decisions," (Oct. 12, 2006) at 5-6.

[13] With respect to waters that are "threatened," as opposed to "impaired," EPA Guidance states:

> *Threatened waters:* States may define "threatened waters" in their assessment and listing methodologies. EPA recommends that states consider as threatened those waters that are currently attaining [water quality standards], but which are expected to not meet WQSs by the next listing cycle (every two years). For example, segments should be listed if the analysis demonstrates a declining trend in a specific water quality criteria (WQC), and the projected trend will result in a failure to meet a criterion by the date of the next list (i.e., 2008 for purposes of the 2006 assessment cycle); or, segments should be listed if there are proposed activities that will result in WQS exceedances.

2006 Guidance at 9, n. 3.

estuary; the severe consequences for the ecosystem that could result if the impairments are not immediately addressed (e.g., eelgrass has been described as "an essential habitat for the estuary, the loss of which would fundamentally alter the ecosystem of the bay");[14] and the ongoing NPDES permitting processes for various wastewater treatment facilities within the watershed. Consistent with EPA recommendations, we urge the State to prioritize, schedule and develop TMDLs for these interrelated water bodies using a watershed approach. *See* EPA Memorandum, "Information Concerning 2008 Clean Water Sections 303(d), 305(b), and 314 Integrated Reporting and Listing Decisions" (Oct. 12, 2006) at 8-9.

VII. If The State Demonstrates That It Cannot Address The Above Water Quality Limited Segments Through Technology-Based Effluent Limitations Or Other Pollution Controls, And Nonetheless Omits The Segments From The Final 303(d) List, EPA Should Disapprove And Supplement Such List.

For the reasons discussed above, the above waters within and associated with the Great Bay estuary must be treated as impaired (or at the very least threatened). Accordingly, the State must either demonstrate that it can and will address these water quality limited segments through technology-based effluent limitations and other pollution controls, or add these segments to its Final 303(d) List. Should the State fail to take either of these actions, EPA should exercise its authority to disapprove the State's proposed Final List and, within thirty days of such disapproval, supplement the Final List with the above-discussed water quality limited segments. 40 CFR § 130.7(d)(2). Alternatively, EPA should specifically require the State to demonstrate good cause for not including such segments on the Final List. 40 CFR § 130.7(b)(6)(iv). Should the EPA proceed with the latter approach, CLF requests that it be notified thereof, and that it be provided an opportunity to comment on any rationale presented by the State for not including these waters and impairments/threats on the Final List.

*   *   *   *   *   *

Again, CLF appreciates the opportunity to provide these comments. Please do not hesitate to contact me should you have any questions.

Respectfully Submitted,

Thomas F. Irwin

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[14] NHEP, *Environmental Indicator Report: Critical Habitats and Species* (March 2006) at 8.

ATTACHMENT A

Eelgrass Distribution in the Great Bay Estuary 2005

A Final Report to

The New Hampshire Estuaries Project

Submitted by

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NewHampshire EstuariesProject

Table of Contents

Introduction

Eelgrass (*Zostera marina*) is an essential habitat for the Great Bay Estuary (GBE) because it provides food for wintering waterfowl and habitat for juvenile fish and shellfish. Eelgrass is the basis of an estuarine food chain that supports many of the recreationally, commercially and ecologically important species in the estuary. Additionally, eelgrass filters estuarine waters, removing both nutrients and suspended sediments from the water column. Eelgrass in the Great Bay Estuary is the largest monoculture in the State of New Hampshire and is considered a vital resource to the State's marine environment. The present report describes and interprets the eelgrass distribution data collected in 2005 for the Great Bay Estuary.

The Great Bay Estuary is experiencing an alarming decline in both eelgrass biomass and distribution that appears to be related to the declining water clarity of the estuary. Eelgrass biomass in Great Bay itself (grams of eelgrass per meter square) has declined steadily (Trowbridge 2006) over the past decade, although the distribution has been relatively constant in Great Bay for the past 10 years at approximately 2,000 acres. In the Piscataqua River, recent declines in both natural and transplanted eelgrass beds are now evident (Short and Beem, in prep) and are a combination of both loss of biomass and loss of distribution. In Portsmouth Harbor in the past 3 years, eelgrass has receded at the deep edge of the meadows, creating an overall loss of distribution which has been accompanied by losses in biomass (Rivers 2007).

In this study, we refer to eelgrass biomass as measured by percent cover, i.e., the percent of the bottom which is vegetated with eelgrass. Biomass is determined through a regression of field-measured biomass and field-measured percent cover. The percent cover map from the aerial distribution can then be converted to biomass (g dry weight eelgrass m^{-2}).

For the first time, *Ruppia maritima* (called here by its common name, ruppia) was observed in large beds in several of the tributaries of GBE, both in aerial photographs and while ground truthing. Therefore, ruppia has been added as an element of the seagrass distribution maps. Ruppia has always been found in the GBE at low levels, particularly in association with salt marsh pannes and in the upper reaches of the estuary. It is mapped in 2005 for the first time because it appeared in large beds in parts of the tributaries where eelgrass could be expected. Ruppia occurs as both an annual and perennial plant, and the persistence of these beds is impossible to predict. Although ruppia is a seagrass and provides some of the functions of an eelgrass meadow, its low canopy height (less than 10 cm in these beds) creates different habitat conditions.

Almost two decades ago, in 1989, there was a dramatic decline in eelgrass area in Great Bay itself to only 300 acres (15% of normal levels). The cause of this crash was an outbreak of a slime mold, *Labryrinthula zosterae*, commonly called "wasting disease". More recently, the greatest extent of eelgrass in the GBE was observed in 1996 after the beds had recovered from the wasting disease episode. The decline in eelgrass biomass seen over the past decade (1996 – 2006) is not a result of wasting disease, and shows all the signs of being caused by anthropogenic impacts, namely nutrient loading and sedimentation.

The University of New Hampshire provided digitized eelgrass distribution information in Great Bay Estuary for the years 1999-2001 to the NHEP database. Additionally, the 2002, 2003 and 2004 eelgrass coverages are now in the NHEP database.

In 2006, the NHEP funded annual monitoring for eelgrass in GBE. We collected aerial photography of eelgrass coverage for 2006 and mapped eelgrass distribution for 2005 from the information gathered in the summer of 2005 (aerial photography and ground truthing). Here, I report on the eelgrass distribution and cover class information for 2005 in the Great Bay Estuary.

Project Goals and Objectives

UNH has now completed the 2005 project under contract to the NH Estuaries Project. The project goals and objectives of the contract were to:

(1) map eelgrass distribution in GBE for 2005 based on aerial photography and ground truth;
(2) acquire aerial photography of the Great Bay Estuary in 2006;
(3) conduct eelgrass ground truth observations of the 2006 aerial imagery.

The final work product is ArcInfo files of eelgrass distribution throughout the Great Bay Estuary in 2005, including all necessary documentation/metadata for the ArcInfo files, and this final report describing the results and any deviations from the protocols established in the QA Project Plan.

Methods

The methods for this project followed the procedures specified in the approved QA Project Plan (Short and Trowbridge, 2003).

Results and Discussion

The shapefiles containing the eelgrass and ruppia distribution data were provided to the NHEP Coastal Scientist by email. Metadata for the shapefiles is as follows:

Codes for cover classes:
- P = 10 to 30 % cover
- H = 30 to 60 % cover
- G [or SB] = 60 to 90 % cover
- D = 90 to 100 % cover
- R = Ruppia

Eelgrass cover below 10% cannot be detected in the aerial photography.

In 2005, eelgrass biomass (shown as percent cover on Figure 1) decreased in the Great Bay Estuary while eelgrass distribution increased slightly. Eelgrass was present throughout much of its expected range in the estuary, although there are still large areas of the estuary that historically supported eelgrass and currently do not, including Little Bay, the Piscataqua River, and parts of Portsmouth Harbor and Little Harbor. Despite a few increases in low biomass eelgrass bed distribution in the upper estuary, the continued decrease in eelgrass biomass in the estuary overall is indicative of poor water quality conditions.

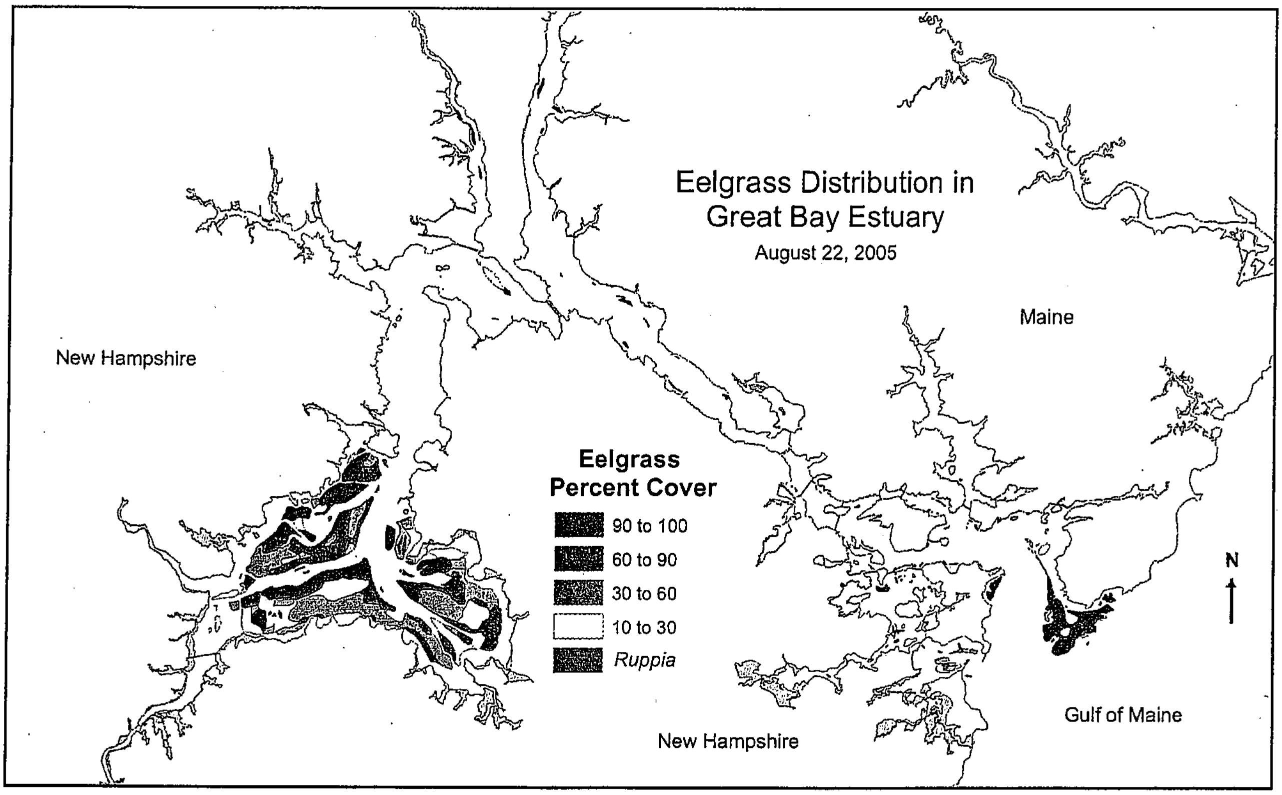
Eelgrass in the central part of Great Bay showed little change in distribution between 2004 and 2005, while biomass decreased overall. In the northwest part of the Bay, near Adams Point, there was a similar pattern, with a decrease in biomass and little change in distribution. On the western side of Great Bay, both biomass and distribution changed little between 2004 and 2005. In the southern Bay, biomass and distribution are little changed overall. The eelgrass bed along the eastern side of Great Bay near Thomas Point lost area but increased in biomass, while in Greenland Bay, eelgrass area increased and biomass remained the same or increased slightly. Most likely, the increase seen in Greenland Bay was present in 2004 as low-density seedlings which were not detectable until 2005 when they were mature plants.

In Little Bay between 2004 and 2005, there was a shift in the eelgrass beds off Dover Point, with an increase of patchy eelgrass and formation of a new bed along the channel. Overall, Little Bay showed some increases in eelgrass biomass or total distribution. There were patches of ruppia in both the Oyster and Bellamy Rivers; these were large, fairly low-biomass patches. There was no eelgrass present in the Oyster River. There are still large areas of Little Bay and the Bellamy River which historically supported eelgrass that remain unvegetated. The single patchy eelgrass bed in the upper Bellamy River present in 2004 was not present in 2005.

In the upper Piscataqua River, both the cover and biomass of eelgrass decreased from 2004 to 2005. The two new eelgrass beds seen in 2003 on the Maine side of the river across from the General Sullivan Bridge disappeared in 2005. Ruppia was found in the upper Piscataqua in three large, low-density beds. On the New Hampshire side of the Piscataqua River, the predominant eelgrass beds remained those restored in the 1993 – 95 New Hampshire Port Mitigation Project. These restored eelgrass beds remained roughly the same from 2004 to 2005 in area, although biomass further decreased.

In Portsmouth Harbor and Little Harbor, some eelgrass beds increased in biomass while others decreased. Overall, there was a loss of eelgrass biomass while area increased slightly. Some losses of biomass and distribution were evident around the Coast Guard station. The eelgrass meadow between Gerrish and Fishing Islands in Portsmouth Harbor remained severely impacted by continued grazing by Canada geese (Rivers and Short 2007). The offshore eelgrass bed southwest of Gerrish Island decreased in biomass while remaining approximately the same size.

For all the areas surveyed in 2005, only Great Bay itself retained eelgrass distributions similar to historic levels, although eelgrass biomass in Great Bay was much lower than seen historically. Eelgrass in Great Bay decreased somewhat between 2004 and 2005, due to losses in biomass, even with gains in distribution. Little Bay showed little change (some increase in area but steady biomass) between 2004 and 2005, with very low levels of eelgrass compared to historical distributions but appearance of large beds of ruppia in the Bellamy River. In the Piscataqua River, an overall decrease was apparent in 2005. The Portsmouth Harbor area experienced a slight increase in eelgrass biomass. Overall, eelgrass in 2005 in the Great Bay Estuary was slightly decreased in biomass and slightly increased in extent, although not consistently throughout the estuary. All of the Great Bay Estuary has decreased eelgrass beds compared to historic distributions (especially in Little Bay and the Piscataqua River), with average biomass levels lower than seen historically.


Eelgrass Distribution in
Great Bay Estuary
August 22, 2005
Maine
New Hampshire
Eelgrass
Percent Cover
90 to 100
60 to 90
30 to 60
10 to 30
Ruppia
N
New Hampshire
Gulf of Maine

Conclusions and Recommendations

1. Increase efforts to lower nitrogen loading to the Great Bay Estuary with particular emphasis on Portsmouth Harbor and the Piscataqua River.
2. Accelerate the implementation of sediment retention structures to reduce the direct sediment input which leads to elevated turbidity in the estuary.
3. Continue annual monitoring of eelgrass in the Great Bay Estuary.
4. Determine the cause of long-term loss of eelgrass percent cover in Great Bay itself and throughout the Estuary.
5. Update the conversion of eelgrass percent cover to biomass through field surveys.
6. Restore eelgrass in Little Bay and the Oyster and Bellamy Rivers.
7. Conduct quantitative monitoring of the wasting disease in the Great Bay Estuary.
8. Institute best management practices in the Great Bay Estuary to reduce boating and mooring impacts to eelgrass.
9. Create an improved map of potential eelgrass habitat for the Great Bay Estuary.
10. Avoid both actual and potential eelgrass habitat when siting other restoration activities or boat moorings and docks in the estuary.

References

Rivers, D.O. 2007. Assessing the suitability of the eelgrass (*Zostera marina* L.) deep edge as an indicator for light reduction in estuarine systems. MS thesis, UNH. 166p.

Rivers, D.O. and F.T. Short. 2007. Impact of grazing by Canada geese (*Branta canadensis*) on an eelgrass (*Zostera marina* L.) meadow, New Hampshire, USA. Marine Ecology Progress Series. 333: 271–279.

Short, F. and N. Beem. unpublished. Eelgrass in the Great Bay Estuary: recent declines of concern, JEL, UNH. May 2007

Short, F. and P. Trowbridge. 2003. UNH Eelgrass Monitoring Program, Quality Assurance Project Plan, Version 1, Final. University of New Hampshire and NH Estuaries Project, June 30, 2003.

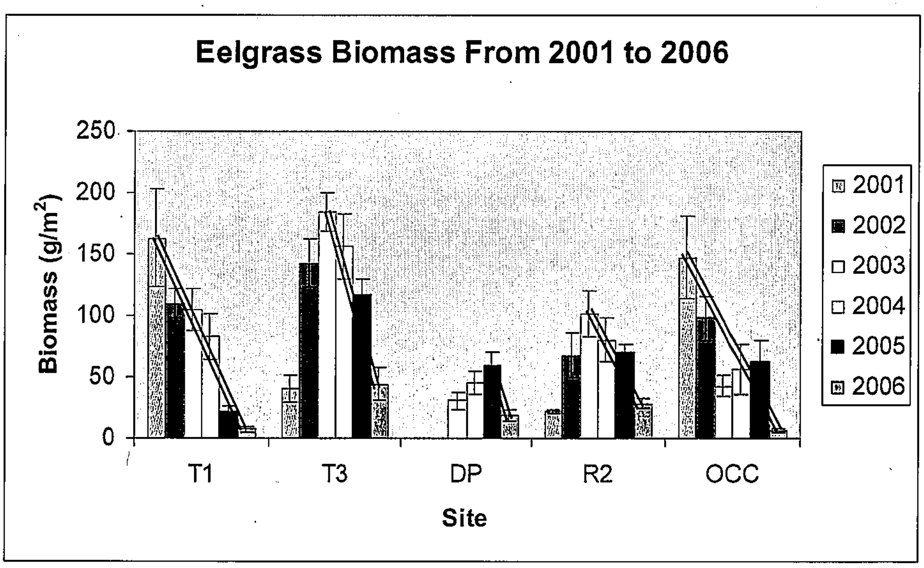
Trowbridge, P. 2006. State of the Estuaries. New Hampshire Estuaries Program, Durham, NH. 32p.

ATTACHMENT B

Eelgrass in the Great Bay Estuary: recent declines of concern

F. Short and N. Beem, JEL, UNH. May 2007

Eelgrass, *Zostera marina* L., declines at both restored and reference areas of the Great Bay Estuary (GBE), New Hampshire, suggest a reduction in the health condition of the estuary. The NH Estuary Program reports concomitant increases in both dissolved inorganic nitrogen (DIN) and suspended sediments. The eelgrass beds, transplanted in 1994 as mitigation for habitat loss due to port development, reached comparable functions and values to natural reference sites within 6 years of transplanting. However, data from 2001 to the present shows significant decline in plant parameters, especially eelgrass biomass, density, and leaf area index. Between 2005 and 2006, eelgrass biomass decline ranged from 59 to 90 percent at the NH Port restored and reference sites. The overwhelming eelgrass decline at all sites indicates that these trends are the result of an estuary-wide factor. DIN concentrations in GBE have increased 59% in the past 25 years, with the single largest contributor of nitrogen being wastewater treatment facilities, clearly linked to increased human population. Additionally, increased impervious surface in the watershed likely results in increased suspended sediments in GBE, limiting eelgrass growth. The linkage between human activity and declining eelgrass populations in GBE and the high cost of remediation necessitates immediate outreach efforts to educate the local community and raise awareness of the consequences of losing critical eelgrass habitat.



NH Port Project eelgrass sites:

T1 & T3 are Piscataqua River transplant sites
DP is the natural reference site at Dover Point in Little Bay
R2 is the natural reference site in the Piscataqua River
OCC is the natural reference site in Outer Cutts Cove at the NH Port Project in the Piscataqua River

See also for background on NH Port Project eelgrass sites: Evans, N.T. and F.T. Short. 2005. Functional trajectory models for assessment of transplant development of seagrass, *Zostera marina* L., beds in the Great Bay Estuary, NH, USA. Estuaries 28: 936–947.

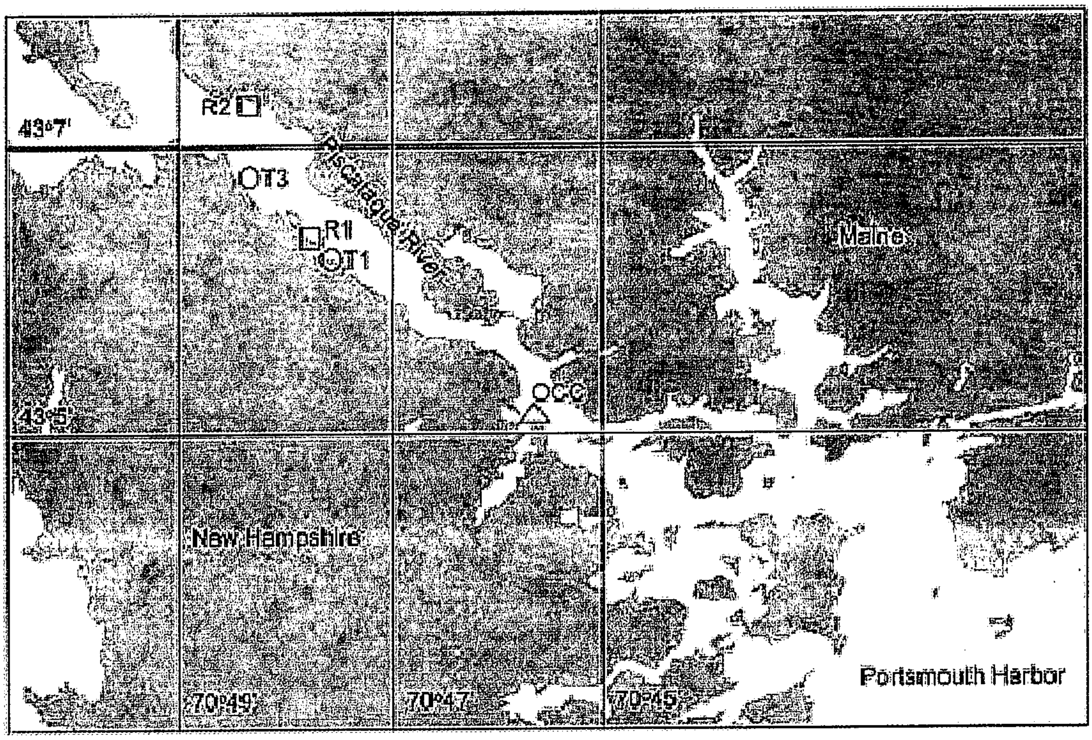


Fig. 1. Map of the Piscataqua River, part of the Great Bay Estuary in New Hampshire and Maine, USA. Squares indicate the location of eelgrass reference sites (R1 and R2); the triangle represents the New Hampshire Port Authority construction site, Outer Cutts Cover (OCC), part of which was used as a reference site in this study; circles indicate the location of transplant sites (T1 and T3).

ATTACHMENT C

Figures

Figure 1. Map of eelgrass study sites within the Piscataqua River in the Great Bay Estuary, New Hampshire. Squares indicate reference sites and circles indicate transplant sites.

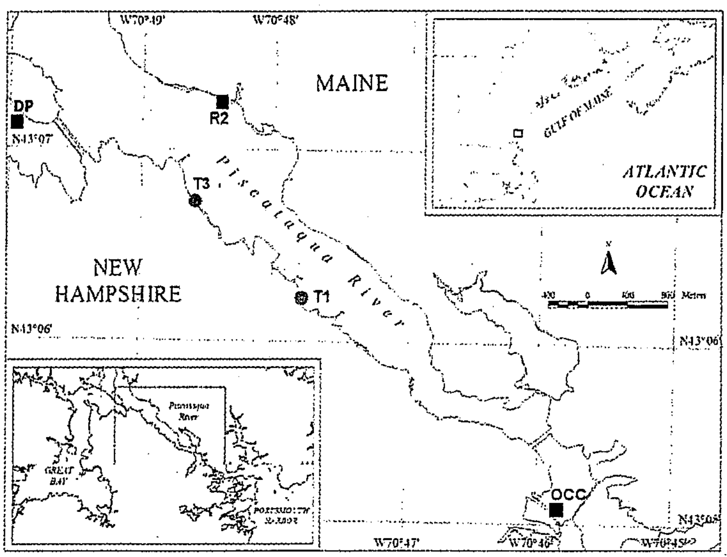


Figure 2. Simple regressions of the effects of time on mean (±SE) eelgrass biomass. Sites are oriented moving up-estuary.

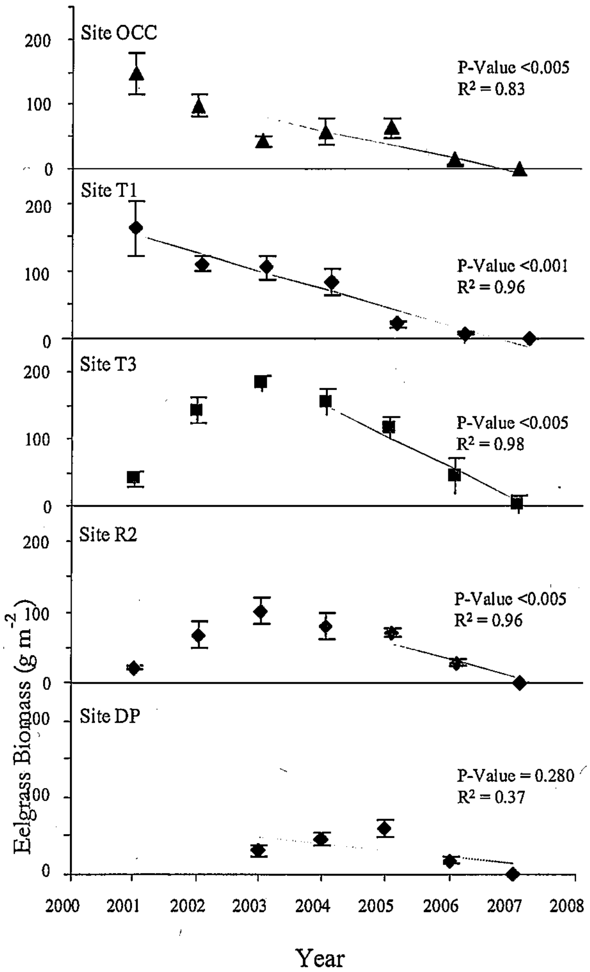


Figure 3. Mean (±SE) eelgrass three-dimensional canopy structure at transplant (T1, T3) reference (DP, R2, OCC) sites from 2001 through 2007. Sites are oriented up-estuary moving left to right.

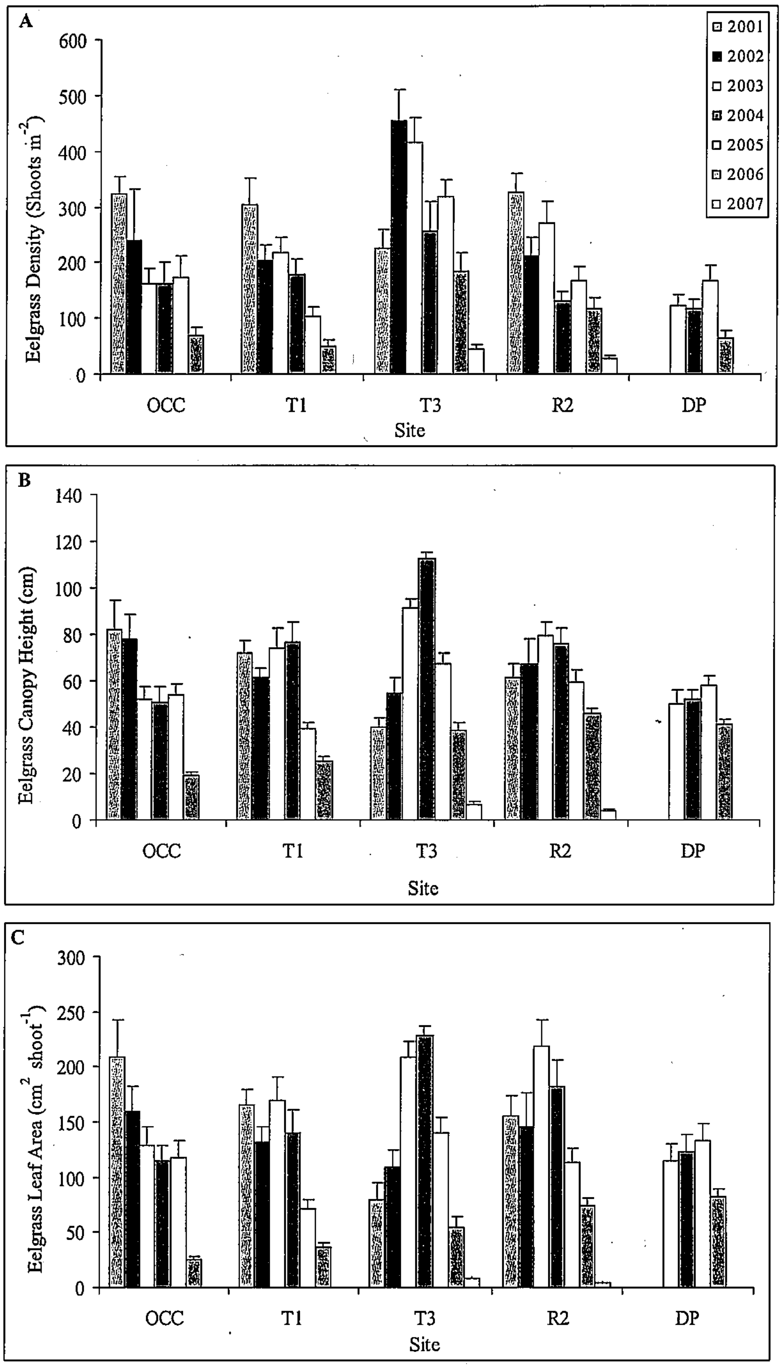
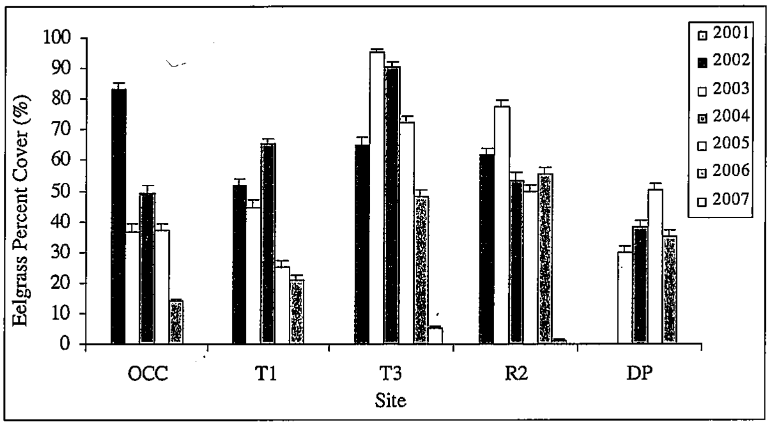


Figure 4. Mean (±SE) eelgrass percent cover at transplant (T1, T3) reference (DP, R2, OCC) sites from 2001 through 2007. Sites are oriented up-estuary moving left to right.

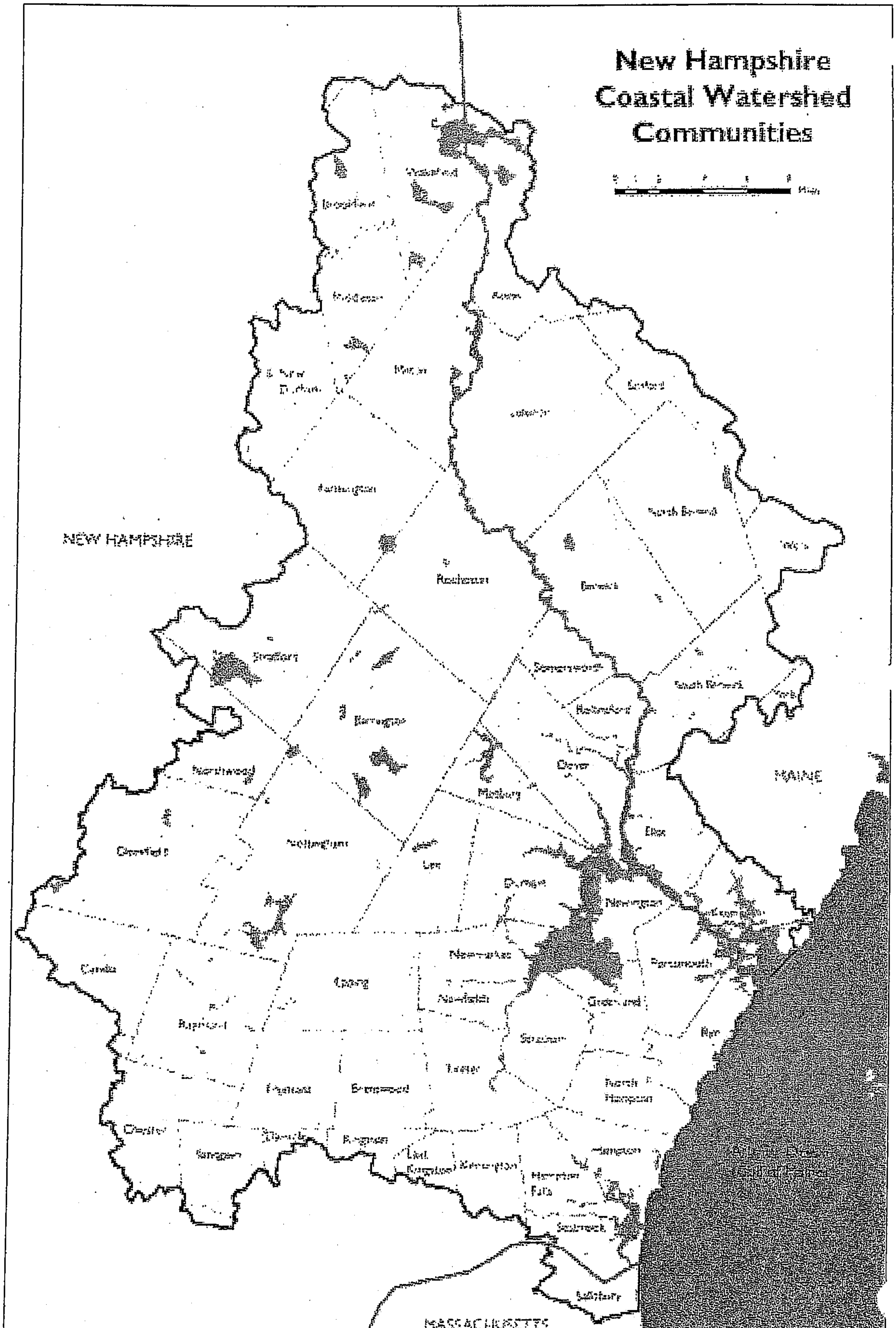


ATTACHMENT D

STATE OF THE ESTUARIES

2006

New Hampshire Estuaries Project



New Hampshire
Coastal Watershed
Communities
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
Wakefield
Middleton
New Durham
Milton
Lebanon
Sanford
Farmington
North Berwick
Rochester
Berwick
Strafford
Somersworth
South Berwick
Rollinsford
Barrington
Dover
Northwood
Madbury
Eliot
Deerfield
Nottingham
Lee
Durham
Newington
Candia
Newmarket
Portsmouth
Epping
Newfields
Greenland
Raymond
Stratham
Rye
Fremont
Brentwood
Exeter
North
Hampton
Chester
Sandown
Danville
Kingston
East
Kingston
Kensington
Hampton
Hampton
Falls
Seabrook
Salisbury

The New Hampshire Estuaries Project

The NHEP is part of the U.S. Environmental Protection Agency's (EPA's) National Estuary Program which is a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuaries. The NHEP's Comprehensive Conservation and Management Plan for New Hampshire's estuaries was completed in 2000 and implementation is ongoing. The Management Plan outlines key issues related to management of New Hampshire's estuaries and proposes strategies that are expected to collectively preserve and protect the state's estuarine resources.

The NHEP's priorities were established by local stakeholders and include water quality improvements, shellfish resource enhancements, habitat protection, improved land development patterns, habitat restoration, and outreach activities to develop broad-based support and encourage involvement of the public, local governments, and other interested groups. The NHEP and its many partners undertake projects and activities to address these priorities in the New Hampshire coastal watershed. The coastal watershed that drains water into the state's major estuary systems – the Great Bay Estuary and Hampton-Seabrook Harbor – and other coastal waters via rivers and streams spans three states with approximately 80 percent of the area located in New Hampshire. The NHEP works with 42 New Hampshire communities that are entirely or partially located within the coastal watershed.

REPORT INTRODUCTION

The 2006 State of the Estuaries Report includes twelve indicators intended to report on the health and environmental quality of New Hampshire's estuaries.

The New Hampshire Estuaries Project (NHEP) developed and now implements a Monitoring Plan to track environmental indicators, inform management decisions, and report on environmental progress and status. The Monitoring Plan describes the methods and data for 34 indicators used to determine if the environmental goals and objectives of the Management Plan are being met. For each indicator, the Monitoring Plan defines the monitoring objective, management goal, data quality objectives, data analysis and statistical methods, and data sources. Just as implementation of the Management Plan for New Hampshire's estuaries involves the collaboration of many organizations and agencies, the NHEP Monitoring Plan relies on data compiled from organizations that are leaders in the management and protection of the state's estuaries and coastal watershed resources.

Every three years, the NHEP prepares a State of the Estuaries report that includes information on the status and trends of a select group of environmental indicators from the coastal watershed and estuaries. The report provides the NHEP, natural resource managers, local officials, conservation organizations, and the public with information on the effects of management decisions and actions.

Prior to developing each State of the Estuaries report, the NHEP publishes four technical data reports ("indicator reports") that illustrate the status and trends of the complete collection of indicators tracked by the NHEP. Each report focuses on a different suite of indicators: Water Quality, Shellfish, Critical Habitats and Species, and Land Use and Development. These reports are available from the NHEP website, www.nhep.unh.edu.

The 2006 State of the Estuaries Report communicates the status of 12 out of the 34 environmental indicators tracked by the NHEP. For each of these key indicators it provides the reader with the associated NHEP management goal and an explanation of supporting data. For some of the 12 indicators, additional information from supporting or related indicators is presented to further explain trends or to provide context for the primary indicators.

The interpretations of the indicators in this report were peer reviewed by the 15 member NHEP Technical Advisory Committee and other experts in relevant fields, including university professors, researchers, and state and federal environmental managers from a variety of disciplines and perspectives. Therefore, the conclusions of this report represent the current scientific consensus regarding conditions in New Hampshire's estuaries.

FOCUS AREAS

- [ ] *Water Quality*
- [ ] *Shellfish*
- [ ] *Critical Habitats & Species*
- [ ] *Land Use & Development*

The environmental quality of New Hampshire's estuaries is good compared with estuaries across the country; but, conditions are changing. Some of the changes are positive, although more of the trends are troubling.

Several indicators of water quality show improvement.

- Bacteria concentrations in the water are decreasing during dry weather conditions.
- Toxic contaminant levels in the water and sediments are at levels of minimal concern. Mussels, clams, and oysters have decreasing toxic contaminant concentrations that are below national guidance values. Tests indicate that organisms living in the sediments are affected by toxic contaminants in only 0.3 percent of the estuary.

However, more indicators suggest that the ecological integrity of the estuaries is under stress or may soon be heading toward a decline.

- Oyster and clam populations are at or approaching the lowest levels ever recorded. Trends suggest that clam populations follow a cyclical boom-and-bust pattern, but the oyster populations appear to be experiencing a slow, steady decline.
- Impervious surfaces are being added to the watershed at an average rate of 1,185 acres per year. In 2005, eight percent of the watershed's land area was covered by impervious surfaces. Land consumption per person is increasing, which is an indicator of sprawling growth patterns.
- Nitrogen concentrations in Great Bay have increased by 59 percent in the past 25 years. Negative effects of excessive nitrogen, such as algae blooms and low dissolved oxygen levels, are not evident. However, the estuary cannot continue to receive increasing nitrogen levels indefinitely without experiencing a lowering of water quality and ecosystem changes.
- Eelgrass coverage in the Great Bay has declined slightly since 1996. During the same period, eelgrass biomass in Great Bay has experienced a more significant decrease. The causes of these declines are uncertain, but loss of water clarity, disease, excess nitrogen, and nuisance macroalgae are all contributing factors.
- Dissolved oxygen concentrations consistently fail to meet state water quality standards in the tidal tributaries to the Great Bay Estuary. So far, the dissolved oxygen levels in the larger embayments are not below state water quality standards.

In an attempt to counteract these trends, the NHEP and others have worked to conserve land, restore habitats, and eliminate pollution sources in the coastal watershed. Over the past three years, 12,037 acres in the coastal watershed have been permanently protected from development. Currently, 54,622 acres, or 10.7 percent of the watershed land area, are protected including 7,009 acres protected by the Great Bay Resource Protection Partnership. The New Hampshire Coastal Program has restored 279 acres of salt marsh in the past six years. The University of New Hampshire (UNH) has completed restoration projects for 3.18 acres of oyster beds and 1.75 acres of eelgrass. The NHEP, state agencies, watershed groups, and municipalities have identified and eliminated many sources of bacteria pollution, and as a result, more areas of the estuaries are open for shellfish harvesting.

Available environmental data indicate that New Hampshire's estuaries still retain many positive attributes and serve important ecological functions. However, the effects of human population growth and development on the estuaries are increasingly evident. Unfortunately, the potential impacts on future ecological integrity are poorly understood.

Indicator	Question	Answer	Implication/Trend
Dry weather bacteria concentrations (page 6)	Have fecal coliform bacteria levels in the Great Bay Estuary changed over time?	Yes. The bacteria concentrations in Great Bay have decreased by 73% over the past 16 years, but the trend has slowed recently.	⊕
Toxic contaminants in shellfish tissue (page 8)	Have concentrations of toxic contaminants in the tissues of shellfish changed over time?	Yes. The concentrations of several contaminants have decreased by 17% to 68% over the past 12 years and no concentrations have increased.	⊕
Toxic contaminants in sediments (page 10)	Do sediments in the estuaries contain toxic contaminants that might harm benthic organisms?	Yes, but rarely. Organisms living in the sediments might be adversely affected by toxic contaminants in only 0.3% of the estuaries.	⊕
Nitrogen in Great Bay (page 12)	Have nitrogen concentrations in Great Bay changed significantly over time?	Yes. Dissolved inorganic nitrogen concentrations have increased in Great Bay by 59% in the past 25 years.	⚠
Dissolved oxygen (page 14)	How often do dissolved oxygen levels in the Great Bay Estuary fall below state standards?	Rarely in the bays and harbors but often in the tidal rivers.	⚠
Oysters (page 16)	Has the number of harvestable oysters in the Great Bay Estuary changed over time?	Yes. The number of harvestable oysters has declined 95% since 1993.	⊖
Clams (page 18)	Has the number of harvestable clams in Hampton-Seabrook Harbor changed over time?	Yes. The current number of harvestable clams is 31% of the average level and decreasing.	⊖
Eelgrass (page 20)	Has eelgrass habitat in Great Bay changed over time?	Yes. Eelgrass cover in the Great Bay has declined by 17% between 1996 and 2004.	⚠
Habitat restoration (page 22)	Are habitats being restored?	Yes for salt marsh, but oyster and eelgrass habitats have been restored at a slower rate.	⊕
Impervious surfaces (page 24)	How much of New Hampshire's coastal watershed is covered by impervious surfaces?	In 2005, 8% of the land area of the watershed was covered by impervious surfaces, and 10 subwatersheds had greater than 10% impervious surface cover.	⊖
Sprawling growth (page 26)	Is the coastal watershed experiencing "sprawl-type" development?	Yes. From 1990 and 2005, land consumption increased from 0.152 to 0.217 acres of impervious surface per person.	⊖
Land conservation (page 28)	How much of the coastal watershed is protected from development?	Currently, 54,622 acres in the watershed are protected, which amounts to 10.7% of the land area.	⊕

Key to Implication/ Trend Classifications:

⊕ Positive

The trend or status of the indicator demonstrates improving conditions, generally good conditions, or substantial progress relative to the management goal.

⚠ Cautionary

The trend or status of the indicator demonstrates possibly deteriorating conditions: however additional inform[illegible] or data are needed to fully assess the observed conditions or environmental response.

⊖ Negative

The trend or status of the indicator demonstrates deteriorating conditions, generally poor conditions, or minimal progress relative to the management goal.

Have fecal coliform bacteria levels in the Great Bay Estuary changed over time?

YES. THE BACTERIA CONCENTRATIONS IN GREAT BAY HAVE DECREASED BY 73 PERCENT OVER THE PAST 16 YEARS, BUT THE TREND HAS SLOWED RECENTLY.

Why this is important

Fecal coliform bacteria in surface waters may indicate the presence of pathogens due to sewage contamination. Pathogens, which are disease-causing microorganisms, pose a public health risk and are the primary reason why shellfish beds are closed to harvesting.

Explanation

At all four of the long-term water quality monitoring stations in the Great Bay Estuary, the trend has been a decrease in the fecal coliform concentrations during dry weather over the past 13 to 16 years. For example, in the middle of Great Bay at Adams Point, fecal coliform concentrations decreased by 73 percent between 1989 and 2004 (Figure 1). This result is encouraging because it indicates that the collective input from the Bay's many tributaries has decreased.

Dry weather fecal coliform contamination is an indication of sewage contamination from faulty septic systems, overboard marine toilet discharges, wastewater treatment facility failures, cross connections between sanitary sewer and stormwater systems, livestock, wildlife, re-suspension of contaminated sediments, and residual stormwater-related pollution. Wastewater treatment facility upgrades and removal of sewage inputs from stormwater sewer systems are likely major contributors to the decreasing trends.

It is important to note that fecal coliform concentrations have remained relatively constant in recent years, and there are still many closures of shellfish beds due to bacterial pollution, particularly after rain events. Moreover, long-term trend data are only available at four locations in the estuaries and these locations may not be representative of all areas.

NHEP Goal: Achieve water quality in the Great Bay Estuary and Hampton-Seabrook Harbor that meets shellfish harvest standards by 2010.

Pipe discharging water into Great Bay

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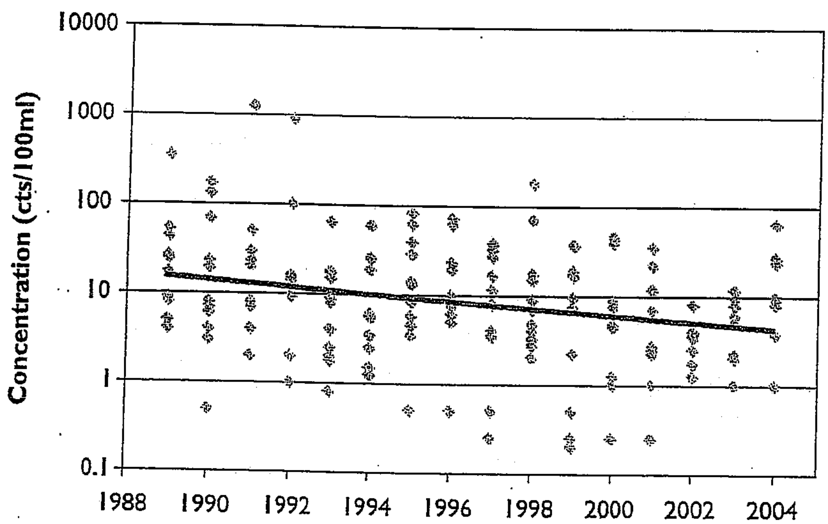
KEEPING SEWAGE OUT OF THE ESTUARIES

Stormwater runoff is a major contributor to bacteria pollution. However, even during dry weather, certain bacteria pollution sources are problematic. Failing septic systems can be a constant source of bacteria pollution, as can illicit connections (or cross connections) between sanitary sewer systems and storm sewer systems. In some cases, pipes are misconnected to storm drainage systems, resulting in discharge of untreated sanitary waste to the estuaries. In others, sanitary waste leaches from old and leaky or broken pipes and is discharged to stormwater drainage that flows into surface waters.

The NHEP has supported the remediation of illicit connections in 16 seacoast communities, resulting in cleaner, safer waters. NHEP grant funds have supported the detection and elimination of more than 60 illicit connections in the last seven years. Detection usually begins with water testing of discharges from storm drainage outfalls during dry weather followed by smoke tests, dye tests, video surveillance, or other detection methods within the drain system to locate the illicit connections. After an illicit connection is detected, the sanitary sewer pipes are properly connected to the wastewater infrastructure so that waste is treated, rather than discharged into streams and estuaries.

Fecal coliform bacteria concentrations during dry weather at Adams Point in Great Bay (Figure 1)



Data Source: UNH Jackson Estuarine Laboratory

TIDAL BATHING BEACH POSTINGS There is an increasing trend in the number of advisories issued at tidal beaches in the coastal watershed due to elevated bacteria levels. Between 1996 and 2002, there were no advisories issued for the tidal beaches. However, in the past three years, there has been at least one advisory per year at the tidal beaches. The increased number of advisories may be a result of a change in sampling protocols used by the NH Department of Environmental Services Beach Program or an increase in local bacterial sources. Regardless, beach advisories warrant attention because they indicate water quality problems.

Have concentrations of toxic contaminants in the tissues of shellfish changed over time?

YES. THE CONCENTRATIONS OF SEVERAL CONTAMINANTS HAVE DECREASED BY 17 TO 68 PERCENT OVER THE PAST 12 YEARS AND NO CONCENTRATIONS HAVE INCREASED.

WHY THIS IS IMPORTANT

Mussels, clams, and oysters accumulate toxic contaminants from polluted water in their tissues. In addition to being a public health risk, the contaminant level in shellfish tissue is a long-term indicator of water quality in the estuaries.

EXPLANATION

The Gulf of Maine Council's (GOMC's) Gulfwatch Program uses blue mussels (*Mytilus edulis*) as the indicator species for shellfish bioaccumulation of toxic contaminants. Between 1993 and 2004, none of the 13 mussel sampling stations in New Hampshire's estuaries registered toxic contaminant levels greater than U.S. Food and Drug Administration (FDA) guidelines. Mercury and polychlorinated biphenyls (PCBs) levels were well below FDA guidelines; however, lead levels approached the recommended limits in some locations. Since shellfish collect toxic contaminants in their flesh when they feed by filtering water, the acceptable levels of contaminants in these creatures suggest that the concentrations of toxic contaminants in estuarine waters are of minimal concern.

Mussel tissue samples from Portsmouth Harbor, Hampton-Seabrook Harbor, and Dover Point have been tested repeatedly between 1993 and 2004. Trends at these sites suggest that levels of PCBs, the pesticide DDT, lead, and zinc are declining (Figures 2a through 2d). The concentrations of DDT and PCBs decreased at two of the three stations by 33-35 percent and 39-68 percent, respectively. Lead concentrations have decreased by 23 percent in Portsmouth Harbor. At all three stations, the zinc concentrations have fallen between 17 percent and 28 percent. The decreasing PCB and DDT concentrations are probably due to decreased use of these chemicals following bans by the EPA in 1979 and 1972, respectively.

NHEP Goal: Reduce toxic contaminant levels in indicator species to below FDA guidance values.

NHEP employee collects blue mussels at low tide that will be tested for contaminants

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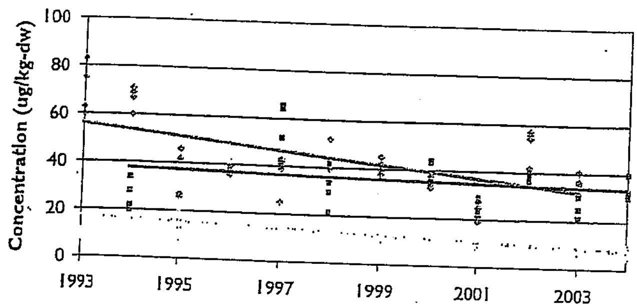
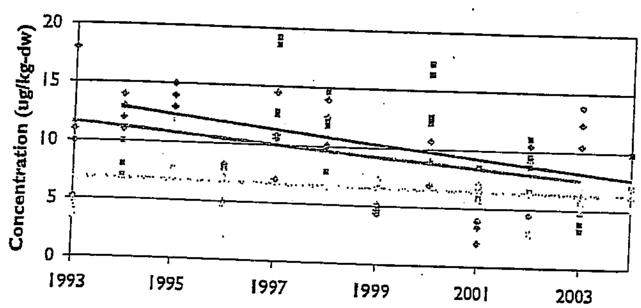
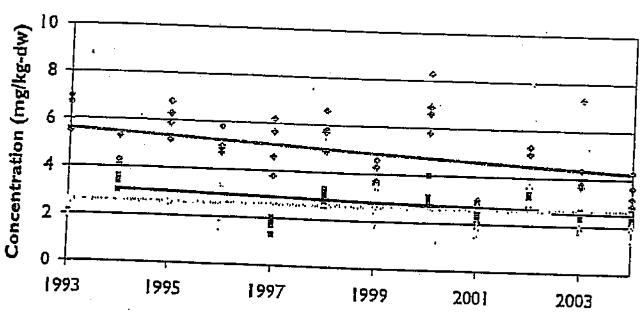
PCBs in mussel tissue (Figure 2a)



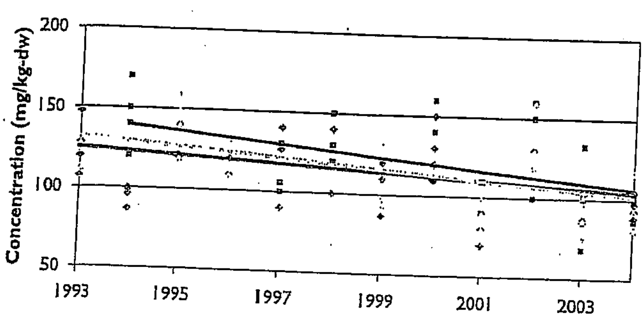
DDT in mussel tissue (Figure 2b)



Lead in mussel tissue (Figure 2c)



Zinc in mussel tissue (Figure 2d)



◦ Portsmouth Harbor ▪ Dover Point · Hampton-Seabrook Harbor

Data Source: GOMC and NHDES, Gulfwatch Program

GULFWATCH PROGRAM

For the past 13 years the GOMC has organized the Gulfwatch monitoring program to assess the types and concentrations of contaminants in blue mussels, *Mytilus edulis*, with the goal of providing baseline contaminant levels on which research questions and management decisions can be based. Mussels are collected annually from over three dozen locations throughout the Gulf of Maine – from Nova Scotia to Massachusetts – and are analyzed for the presence of over 50 types of toxic contaminants. The GOMC's general findings from Gulf-wide analysis of samples indicate that:

- Nearly all measured metal contaminants were detected in mussels from each of the sampling sites.
- Organic contaminants and certain metals were more concentrated in mussels collected near cities and large river mouths, particularly in the southern portion of the Gulf of Maine.
- Tissue concentrations for a few contaminants at some Gulfwatch sites were elevated compared to other regions of North America, although, except for lead in Boston Harbor, no contaminant concentrations exceeded any FDA federal action levels for human consumption.
- Analysis of five benchmark sites from 1991-1997 showed that most contaminants in mussels were decreasing or did not exhibit a trend.

More information on these findings and the Gulfwatch program is available on the GOMC's website: www.gulfofmaine.org/gulfwatch.

The GOMC Gulfwatch program collects and analyzes mussel tissue from two sites in New Hampshire each year. In addition, The NHEP organizes and funds the collection and analysis of mussels from two additional sites in the state each year, plus the collection and analysis of oysters and clams every three years. These additional sites and additional types of shellfish testing improve the coverage for New Hampshire's estuaries and allow better assessment of local sources of pollution.

Do sediments in the estuaries contain toxic contaminants that might harm benthic organisms?

Yes but rarely. Organisms living in the sediments might be adversely affected by toxic contaminants in only 0.3 percent of the estuaries.

Why this is important

Toxic contaminants accumulate in estuarine sediments, and therefore organisms living in the sediments are especially at risk of being impacted by these pollutants. Furthermore, toxic contaminant concentrations in sediments can provide information on both historical and current pollution of the estuaries.

Explanation

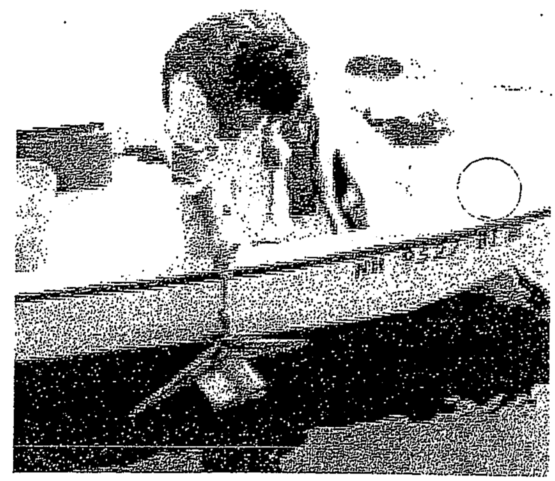
Approximately 12 percent of the estuarine sediments had at least one contaminant with concentrations greater than a screening value (Figure 3). Concentrations above screening values have the potential to pose a threat to organisms that live in the sediments. Elevated levels of contamination occur mainly in the tidal rivers, especially the Cocheco River. The chemicals that exceeded screening values were chromium, lead, silver, polycyclic aromatic hydrocarbons, and the pesticide DDT. Another important observation was the consistently low levels of almost all contaminants at sites in Little Harbor, Little Bay, Hampton-Seabrook Harbor, and in the outer portion of Portsmouth Harbor.

Screening values were set conservatively; therefore, concentrations above screening values do not necessarily mean that organisms in the sediments will be affected by the contaminants. Actual effects on benthic organisms were determined using sediment toxicity and benthic community surveys. These tests showed that the organisms in the sediments were affected by toxic contaminants in only two locations out of 70 tested, or 0.3 percent of the estuary (Figure 4). The two locations were in the Cocheco River and the Lamprey River (Figure 5). Therefore, in most of the locations where toxic contaminants in sediments were above screening values, the organisms did not appear to be affected by the contamination.

The absence of apparent effects on organisms in the sediments does not necessarily mean all aquatic species are unaffected. First, the sediment toxicity and benthic community surveys are only capable of detecting significant impacts to the benthic community. More subtle impacts might have been missed. Second, benthic organisms are just one of many possible aquatic species groups. For bioaccumulative compounds, such as mercury and PCBs, species in higher trophic levels could be at risk even if impacts to benthic organisms are not observed. Finally, the sediments have only been tested for the typical suite of toxic contaminants, not for new classes of chemicals which are emerging as possible threats, such as personal care products and pharmaceuticals.

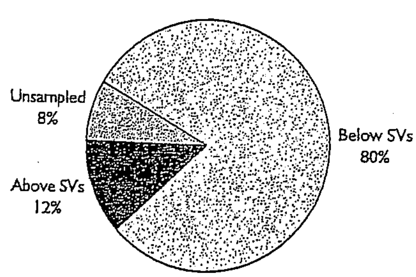
NHEP Goal: No impacts to benthic communities due to sediment contamination.

UNH technician preparing to collect a sediment sample from Great Bay



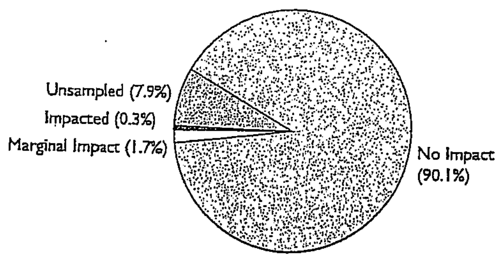
NHEP

Concentrations of toxic contaminants relative to screening values (SVs) (Figure 3)



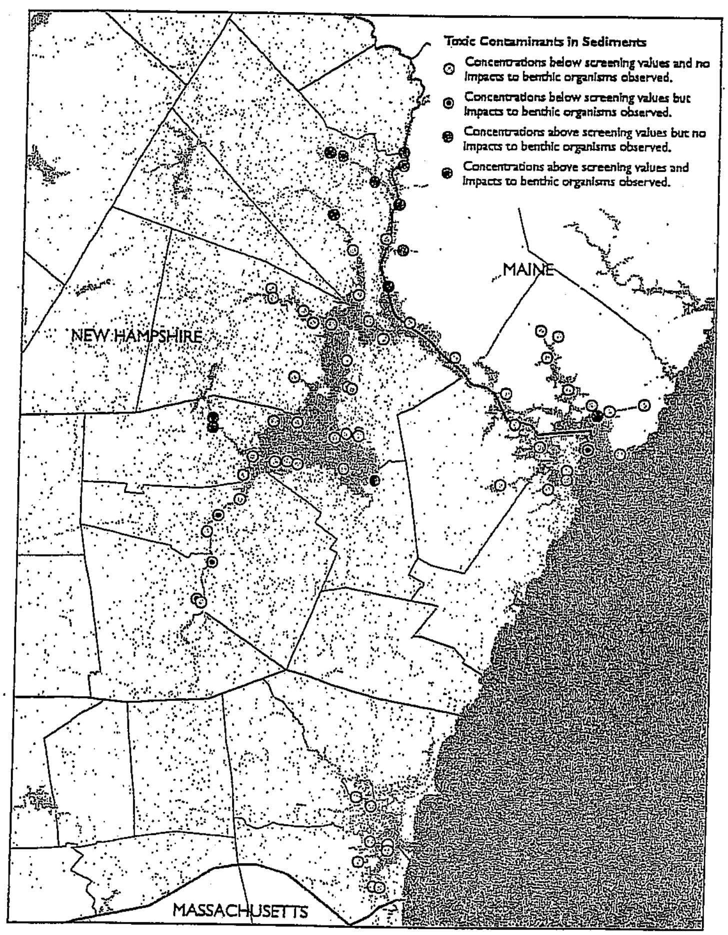
Data Source: EPA, NHDES, and UNH, National Coastal Assessment Survey (2000-2001)

Effects of toxic contaminants on benthic organisms (Figure 4)



Data Source: EPA, NHDES, and UNH, National Coastal Assessment Survey (2000-2001)

Locations of toxic contamination in sediments and impacts to benthic organisms (Figure 5)



Data Source: EPA, NHDES, and UNH, National Coastal Assessment Survey (2000-2001)

VOLUNTEERS CRITICAL IN MONITORING FRESHWATER RIVERS

The quality of freshwater river systems that eventually flow into the estuaries has a large impact on the overall condition of the estuaries. The NHDES Volunteer River Assessment Program (VRAP) organizes water quality monitoring by watershed organizations and other volunteers for freshwater streams and rivers in the coastal watershed. VRAP volunteers measure water quality parameters such as temperature, pH, dissolved oxygen, turbidity, and specific conductance. Recent VRAP water quality reports are available for the Bellamy, Cocheco, Isinglass, Lamprey, and Oyster rivers at www.des.nh.gov/wmb/VRAP.

The Coastal Volunteer Biological Assessment Program (CVBAP) was established in 2005 by the NHDES Bio-monitoring Unit and the NH Coastal Program to educate the public about water quality issues as interpreted through biological data (aquatic macroinvertebrates), build a constituency of volunteers to practice sound water quality management at the local level, and supplement biological data collected by NHDES. The Cocheco River Watershed Coalition, Exeter River Local Advisory Committee, and Oyster River Watershed Association are participating in the program. Through CVBAP these groups' existing water quality monitoring efforts are expanded to include collection of biological data.

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NH DES technicians collecting aquatic invertebrates from the Oyster River

Have nitrogen concentrations in Great Bay changed significantly over time?

YES. DISSOLVED INORGANIC NITROGEN CONCENTRATIONS HAVE INCREASED IN GREAT BAY BY 59 PERCENT IN THE PAST 25 YEARS.

WHY THIS IS IMPORTANT

Excessive nitrogen can cause algae blooms and change species composition of important habitats. Furthermore, decomposition of algae can deplete coastal waters of dissolved oxygen. Both of these effects will impair estuarine functions.

EXPLANATION

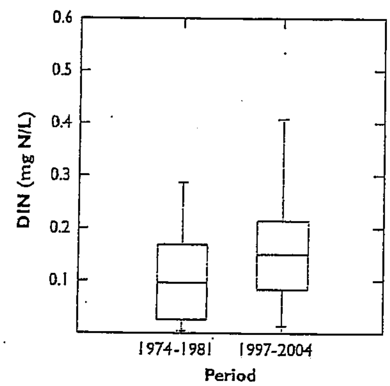
Dissolved inorganic nitrogen (DIN) has been monitored monthly in the estuary since 1991. Clear trends in DIN during this 15 year period are not evident. However, a comparison of historical and recent datasets shows that DIN concentrations have increased in Great Bay by 59 percent between the periods of 1974-1981 and 1997-2004 (Figure 6). During the same period, suspended solids concentrations increased by 81 percent (Figure 7). The change in suspended solids may be related to the nitrogen trend; however, many other factors might have caused the increased suspended solids including variability in rainfall, wind speed and tidal amplitude, localized erosion, recent loss of eelgrass, or loss of filter feeders such as oysters.

Researchers are still debating the possible effects of the increasing DIN concentrations on Great Bay because it is a unique system, both hydrodynamically and biologically, that may respond differently to excess nitrogen than other estuaries. So far, the typical effects of excess nitrogen have not been observed in Great Bay, although DIN concentrations in Great Bay are similar to concentrations in other estuaries where negative effects have been clearly observed. The only increasing trend for chlorophyll-*a*, a surrogate for algae, was observed at a station with very low concentrations. Low dissolved oxygen concentrations only have been found in the tributaries to the Bay, not the Bay itself. However, changes in other parts of the ecosystem, particularly eelgrass cover and biomass, have been observed. There also have been anecdotal reports of increasing populations of nuisance macroalgae in some areas of Great Bay. While a precise threshold for DIN effects is not known, it is certain that the estuary cannot continue to receive increasing nitrogen loads indefinitely without experiencing a lowering of water quality and ecosystem changes.

NHEP Goal: Maintain inorganic nutrients in the Great Bay Estuary, Hampton-Seabrook Harbor, and their tributaries at 1998-2000 baseline levels.

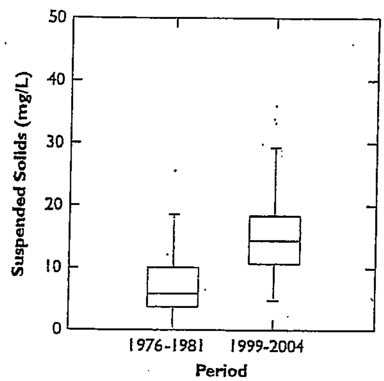
Dissolved inorganic nitrogen concentrations measured at Adams Point at low tide (Figure 6)

Data Source: UNH Jackson Estuarine Laboratory



Suspended solids concentrations measured at Adams Point at low tide (Figure 7)

Data Source: UNH Jackson Estuarine Laboratory



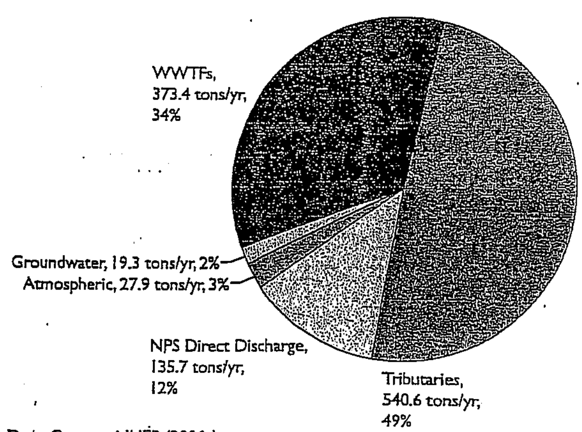
Key to understanding a box and whisker plot: The box and whisker plots in Figures 6 and 7 show the distribution of concentrations measured at the same location during two different periods. The horizontal line in the middle of each box marks the median concentration measured for that period. The lower and upper walls of the box mark the 25th and 75th percentile concentrations, respectively. The lower and upper ends of the "whiskers" (the vertical lines extending from the box) approximate the 5th and 95th percentile concentrations, respectively. Points beyond the whiskers are measurements which are much lower or higher than the rest of the distribution.

NUTRIENT CRITERIA FOR NEW HAMPSHIRE'S ESTUARIES

Excess nutrients are a major concern for water quality and ecological integrity in estuaries. The EPA requires states to develop water quality criteria for estuarine waters which would set limits on nutrients or the negative effects of excess nutrients. The NHEP agreed to lead the effort to develop nutrient criteria for New Hampshire's estuaries because of its technical expertise and strong stakeholder ties. Data from NHEP indicators on dissolved oxygen, chlorophyll-*a*, total suspended solids, eelgrass biomass, and other input and response indicators are being reviewed to better understand nutrient dynamics and impacts in the Great Bay Estuary. The outcome of this analysis will be recommendations to the State Water Quality Standards Advisory Committee for specific criteria to protect the water quality and ecology of New Hampshire's estuaries from excess nutrients.

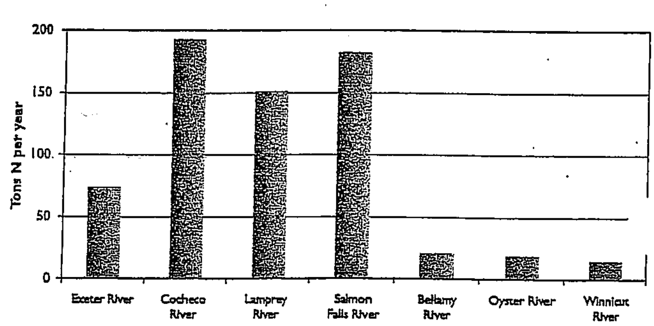
NITROGEN LOAD TO THE GREAT BAY ESTUARY The NHEP estimated that 1,097 tons of nitrogen entered the Great Bay/Upper Piscataqua Estuary in 2002 (Figure 8). Wastewater treatment facilities (WWTFs) contributed 34 percent of the total amount. The largest component of the nitrogen load was nonpoint sources in the watershed tributaries (49 percent) and from the land adjacent to the estuary (12 percent). Nonpoint sources of nitrogen include lawn fertilizers, septic systems, animal wastes, and atmospheric deposition to land. Direct discharge to the Bay from groundwater and direct atmospheric deposition to the Bay represented relatively small overall contributions of nitrogen. The major sources of nitrogen are all related to population growth and associated land development patterns. Figure 9 shows the annual average nitrogen load that was measured for the 2002-2004 period at the head of tide dam for each tributary. The Cocheco, Salmon Falls, and Lamprey rivers supplied the largest nitrogen loads compared with the other tributaries.

Nitrogen loads to the Great Bay and Upper Piscataqua River Estuary in 2002 (Figure 8)



Data Source: NHEP (2006c)

Total nitrogen loads from Great Bay watersheds in 2002-2004 (Figure 9)



Data Source: NHEP (2006c)

How often do dissolved oxygen levels in the Great Bay Estuary fall below state standards?

RARELY IN THE BAYS AND HARBORS, BUT OFTEN IN THE TIDAL RIVERS.

WHY THIS IS IMPORTANT

Fish and many other aquatic organisms need dissolved oxygen in the water to survive. Prolonged periods of low dissolved oxygen can alter aquatic ecosystems.

EXPLANATION

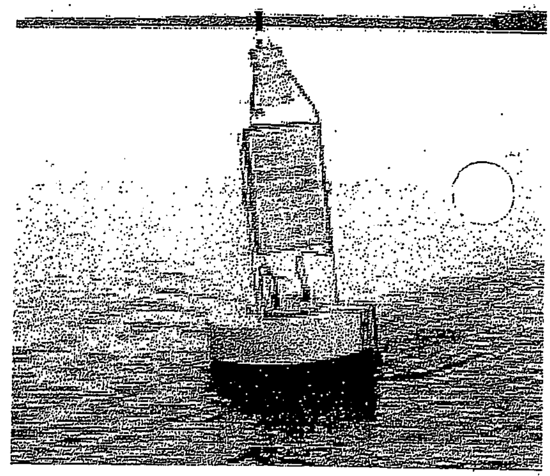
The Great Bay National Estuarine Research Reserve and the NHEP support the maintenance of instruments, called datasondes, at six locations in the Great Bay Estuary to monitor dissolved oxygen and other parameters every 30 minutes. The measurements are used to determine the average dissolved oxygen concentrations during the day. The sampling stations are located in the middle of Great Bay, Portsmouth Harbor, and in the tidal tributaries to the Great Bay Estuary (Figure 10).

The dissolved oxygen concentrations in Great Bay and Portsmouth Harbor consistently meet the 75 percent saturation standard, while exceedences of the standard have been observed in the tidal tributaries (Figure 11). The most exceedences have been observed in the Lamprey River (56 percent of the summer season on average in 2002-2004). Relatively few exceedences of the standard have been observed in the Squamscott, Oyster, and Salmon Falls rivers.

Strong tidal flushing through the estuary and inflow from freshwater streams appear to mix and oxygenate the water well in the large embayments. The causes of sporadic low dissolved oxygen concentrations in the tidal tributaries are unknown. Some possible explanations are algae blooms, benthic organism respiration, and oxygen demand from wastewater treatment facility effluent. In some cases low concentrations may be natural phenomena.

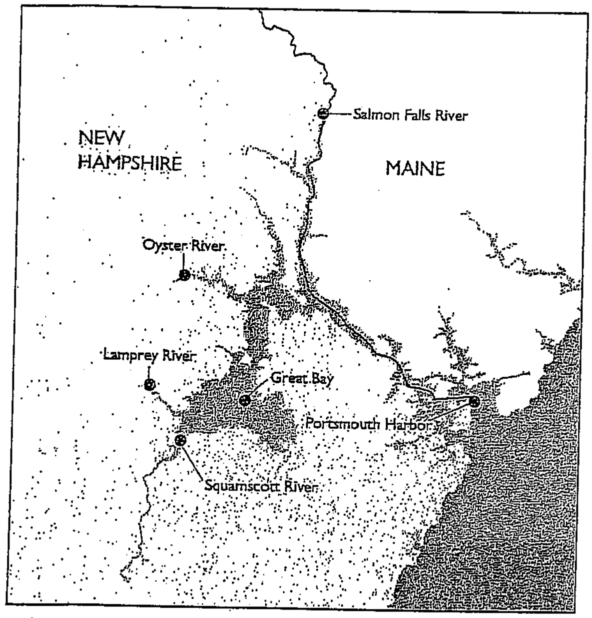
NHEP Goal: No days that exceed the state standard for daily average dissolved oxygen (75 percent saturation).

Datasonde buoy
on Great Bay



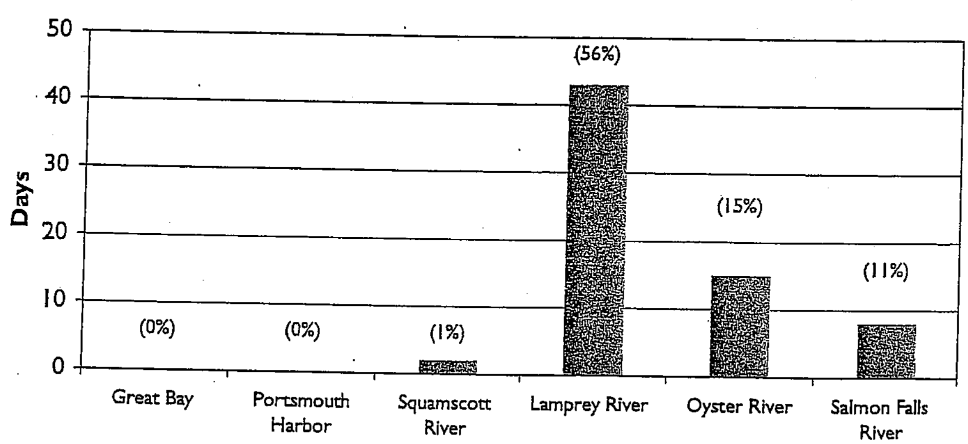
Bridget Finnegan

Datasonde stations in the Great Bay Estuary (Figure 10)



Data Source: UNH Jackson Estuarine Laboratory

Number of summer season days in 2002-2004 with daily average dissolved oxygen less than 75 percent saturation (Figure 11)



Numbers in parentheses are the percent of daily average dissolved oxygen measurements less than 75%.

Data Source: UNH Jackson Estuarine Laboratory, Great Bay National Estuarine Research Reserve System Wide Monitoring Program

DATASONDES

Datasondes are automated monitoring instruments programmed to obtain measurements of specific conductivity, salinity, dissolved oxygen, percent saturation, pH, temperature, water level, and turbidity every half hour. The instruments are deployed continuously during ice-free seasons, except for brief periods when they are removed for cleaning, maintenance, and recalibration. Datasondes are deployed approximately one meter from the bottom and recovered for data download every two to four weeks depending upon the time of year. Deployment and operation of the network of datasondes throughout the Great Bay Estuary is made possible through a partnership between the Great Bay National Estuarine Research Reserve, the NHEP, and the UNH Jackson Estuarine Laboratory.

Has the number of harvestable oysters in the Great Bay Estuary changed over time?

YES. THE NUMBER OF HARVESTABLE OYSTERS HAS DECLINED 95 PERCENT SINCE 1993.

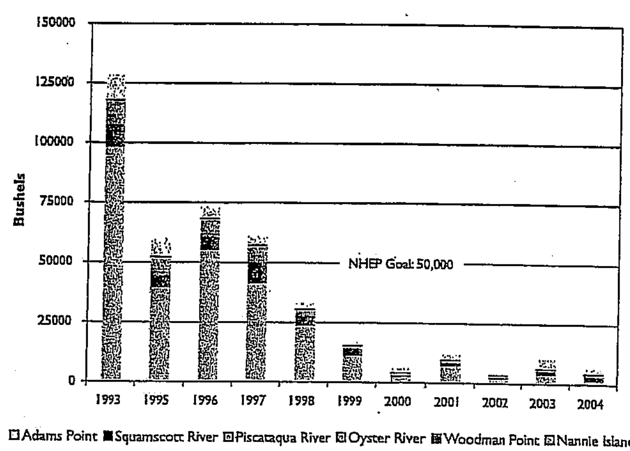
Why this is important

Oysters are excellent indicators of estuarine condition because they are relatively long-lived stationary filter feeders that play important roles in nutrient cycling and water clarity. They also provide food and habitat for other species in the estuary. They are economically important because they support valuable recreational fisheries and have potential as an aquaculture species.

Explanation

Since 1993 the oyster fishery in the Great Bay Estuary has suffered a serious decline (Figure 12). Harvestable oyster standing stock in 2004 was only 11 percent of the NHEP goal of 50,000 bushels and only five percent of the maximum observed standing stock in 1993. Most of the remaining standing stock is in the Nannie Island and Woodman Point beds in Great Bay. The major cause of the decline is thought to be the protozoan pathogens MSX and Dermo that have caused similar declines in oyster fisheries in the Chesapeake and other mid-Atlantic estuaries. There is some uncertainty in the standing stock estimates because, while the oyster densities are typically measured each year, the sizes of the beds have been monitored less frequently.

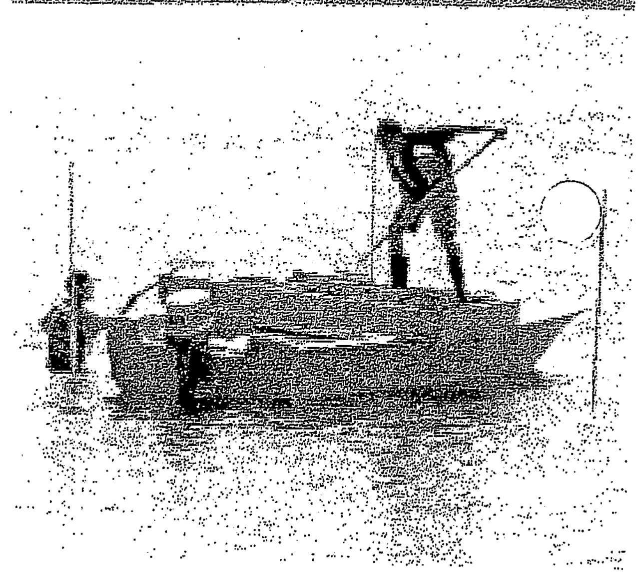
Oyster standing stock in the Great Bay Estuary (Figure 12)



Data Source: NH Fish and Game Department

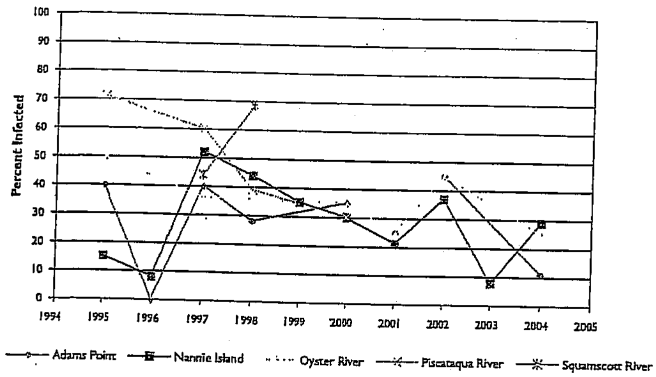
NHEP Goal: Triple the standing stock of harvestable oysters from 1999 levels to 50,000 bushels.

UNH researchers building an experimental oyster reef in Great Bay



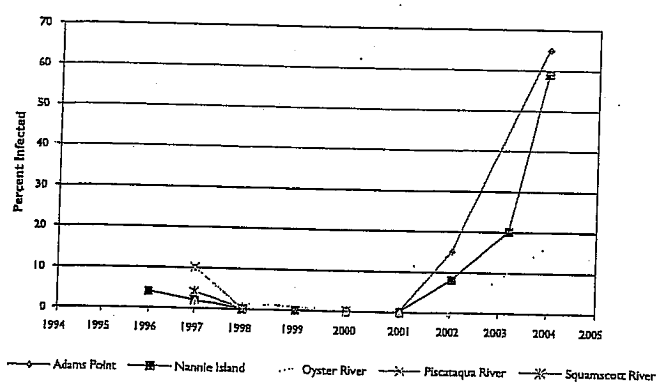
UNH

MSX infection prevalence in Great Bay Estuary oyster beds (Figure 13)



Data Source: NH Fish and Game Department

Dermo infection prevalence in Great Bay Estuary oyster beds (Figure 14)



Data Source: NH Fish and Game Department

RESTORING OYSTER REEFS

Oyster restoration projects are attempting to reverse the declining trends in the number of harvestable oysters by addressing some factors believed to be responsible for their dramatic decline. UNH, with funding and support from the NHEP, Natural Resources Conservation Service, The Nature Conservancy, and the City of Dover, has several active projects. All of the restoration projects use a disease-resistant fast-growth strain of oyster larvae to counteract the effects of the oyster diseases.

For one of the projects, UNH researchers are studying reef structure alternatives in an area near Nannie Island in Great Bay where two reef designs were built and are being evaluated. One design mimics a large reef, while the other imitates a series of smaller reefs clustered together. The researchers are studying each design and evaluating which one best promotes spat abundance, survival, and growth. The reefs were built with crushed granite mounded up eight inches and then seeded with about 200 young oysters per square yard. The research study also compares natural spat density on the constructed reefs to density on natural reefs. Lessons learned from this project will help create a blueprint for future oyster restoration projects. For more information on New Hampshire oyster restoration projects, visit www.oyster.unh.edu.

OYSTER DISEASES There are two diseases that are known to be affecting oysters in the Great Bay Estuary. The disease MSX, which is caused by the protozoa *Haplosporidium nelsoni*, was detected in the Piscataqua River in 1983. The first oyster mortality from the disease was observed in 1995 following a severe drought (Barber et al., 1997). The disease Dermo is caused by the protozoa *Perkinsus marinus*. The NH Fish and Game Department and NHEP have monitored the prevalence of MSX and Dermo in oysters from the Great Bay Estuary every year since 1995 (Figures 13 and 14). No statistically significant change in MSX infection rates at Nannie Island has occurred since the disease was first detected. Approximately 20 percent of the oysters in the Great Bay Estuary are currently infected with MSX. The infection prevalenc of Great Bay Estuary oysters by Dermo was low or zero until recently. Between 2002 and 2004, the prevalence of Dermo infection in the Nannie Island and Adams Point oyster beds shot up from approximately 10 percent to 60 percent. The cause of the increased prevalence of Dermo in these beds is not known.

Has the number of harvestable clams in Hampton-Seabrook Harbor changed over time?

Yes. The current number of harvestable clams is 31 percent of the average level and decreasing.

Why this is important

Soft-shell clams are an important economic, recreational, cultural, and natural resource for the Seacoast region. Recreational shellfishing in Hampton-Seabrook Harbor is estimated to contribute more than $3 million a year to the local and State economy (NHEP, 2000).

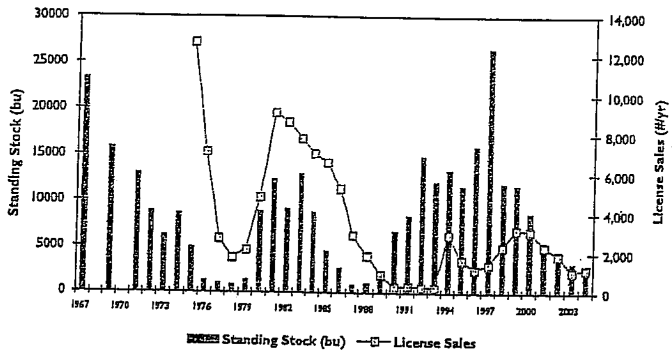
Explanation

The amount of clams of harvestable size in Hampton-Seabrook Harbor, also known as standing stock, has been monitored by FPL Energy Seabrook Station over the past 38 years (Figure 15). The standing stock has undergone several 12-15 year cycles of growth and decline. Peak standing stocks of approximately 23,000, 13,000, and 27,000 bushels occurred in 1967, 1983, and 1997, respectively. Between the peaks, there have been crashes of the fishery in 1978 and 1987, with standing stock less than 1,000 bushels. Since 1997, the standing stock has been dropping once again, but the 2004 levels have not yet reached the levels observed during the crashes in 1978 and 1987. The standing stock in 2004 was 2,630 bushels which is 31 percent of the NHEP management goal of 8,500 bushels.

The cause of the current decline in harvestable clam populations is unknown. A NHEP study in 2001-2002 concluded that predation of juvenile clams by green crabs and strong currents in the harbor were potential factors in the decline (Beal, 2002). Other observers have expressed concern that harvesting, which appears to be correlated with clam standing stock (Figure 15), may contribute to the decline.

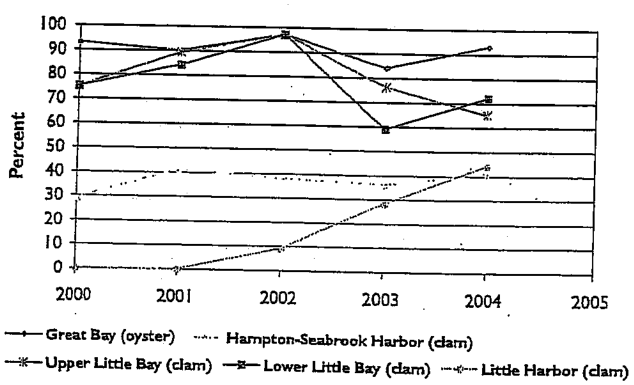
NHEP Goal: Maintain or exceed the average standing stock of harvestable clams in Hampton-Seabrook Harbor flats (8,500 bushels).

Clam standing stock in Hampton-Seabrook Harbor and recreational clamming license sales (Figure 15)



Data Source: FPL Energy Seabrook Station and NH Fish and Game Department

Percent of possible shellfish harvesting acre-days (Figure 16)



Data Source: NHDES Shellfish Program

NHDES SHELLFISH PROGRAM: PROTECTING PUBLIC HEALTH

The NHDES Shellfish Program determines which areas meet standards for shellfish harvesting and consumption. Staff regularly collect water samples from over 75 locations in state tidal waters and shellfish meat samples from 15 locations. Water and shellfish samples are sent to state labs in Concord where they are tested for bacterial contamination. In addition, the program monitors concentrations of the paralytic shellfish poison toxin, commonly referred to as "red tide."

To determine if shellfish growing areas meet standards for harvesting and consumption, the NHDES Shellfish Program conducts indepth environmental studies called sanitary surveys. Surveys involve intensive water monitoring and shoreline inspections coupled with an analysis of the impacts of wastewater treatment plants, private septic systems, development, boating, and other activities that affect shellfish growing areas because of pollution. To date the program has completed sanitary surveys for approximately 85 percent of the estuarine areas. Most of the approved shellfish harvesting areas are open on a conditional basis, meaning that certain conditions, such as rainfall or sewage releases from wastewater treatment plants, will close areas to harvest until the NHDES Shellfish Program determines that the area meets standards for consumption.

The NHEP has supported the NHDES Shellfish Program activities since they began in the late 1990s by providing funding to complete sanitary surveys and more recently to support laboratory analysis of water and shellfish tissue samples. As a result of these efforts, the NHDES Shellfish Program was officially recognized as being compliant with the National Shellfish Sanitation Program by the U.S. Food and Drug Administration in October 2002.

SHELLFISH HARVESTING OPPORTUNITIES The NHDES Shellfish Program measures the opportunities for shellfish harvesting using "acre-days," which is the product of the acres of shellfish growing waters and the number of days that these waters are open for harvest. The acre-days indicator is reported as the percentage of the total possible acre-days of harvesting for which the shellfish waters are actually open. In most cases, poor bacterial water quality restricts harvesting, making the acre-day indicator a good integrative measure of the degree to which water quality in the estuary is meeting fecal coliform standards for shellfish harvesting. Shellfishing opportunities in the open portions of the estuaries vary by location (Figure 16). In Great Bay, the shellfishing acre-days were nearly 90 percent of the possible amount in 2000-2004. In Hampton-Seabrook Harbor and Little Harbor, the acre-day percentage was only slightly above 40 percent for the same period. In both of these harbors, poor water quality due to elevated bacteria concentrations occurs after even small rain storms causing closures. However there has been an improving trend in the Little Harbor growing area. This area was closed to shellfishing before 2001. By 2004, it was open 44 percent of the possible acre-days. The areas in Upper and Lower Little Bay were closed more often in 2003 and 2004 than previously because of heavy rainfall, wastewater treatment facility overflows, and the extended presence of boats in the mooring fields.

Has eelgrass habitat in Great Bay changed over time?

Yes. Eelgrass cover in the Great Bay has declined by 17 percent between 1996 and 2004.

Why this is important

Eelgrass (*Zostera marina*) is essential to estuarine ecology because it filters water, stabilizes sediments, provides food for wintering waterfowl, and provides habitat for juvenile fish and shellfish. Healthy eelgrass habitat both depends on and contributes to good water quality.

Explanation

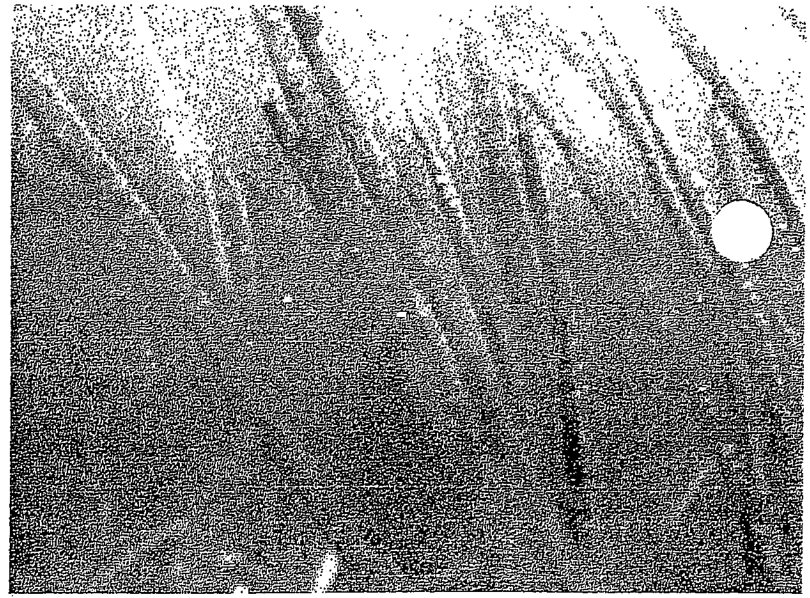
Throughout the 1990s, the total eelgrass cover in Great Bay was relatively constant at approximately 2,000 acres (Figure 17). In 1988 and 1989, there was a dramatic crash of the eelgrass beds down to 300 acres (15 percent of normal levels). The cause of this crash was an infestation of a slime mold, *Labryrinthula zosterae*, commonly called "wasting disease" (Muehlstein et al., 1991). The greatest extent of eelgrass was observed in 1996 (2,421 acres) after recovery from the wasting disease. The current (2004) extent of eelgrass in Great Bay is 2,008 acres, which is 17 percent less than the maximum extent observed in 1996.

The biomass of eelgrass in Great Bay has experienced a more significant decline relative to the levels observed in 1996 (Figure 17). Biomass is the combined weight of eelgrass plants in the bay. In 1990, 1991, and 1995, the biomass was low due to wasting disease events. Superimposed on these rapid events has been a gradual, decreasing trend in eelgrass biomass that does not appear to be related to wasting disease. The current eelgrass biomass level for Great Bay is 948 metric tons, which is 41 percent lower than the biomass observed in 1996.

The specific cause of the decline in eelgrass cover and biomass is unclear, but appears to be related to a reduction in the amount of light reaching the plants. Eelgrass is sensitive to water quality, especially water clarity. The observed changes in eelgrass cannot be linked directly to a water quality trend in Great Bay, although increasing concentrations of suspended solids have been observed at Adams Point. The effects of the wasting disease are easily observed on the plants and the gradual decline of the past decade is not consistent with a wasting disease event. There have been anecdotal reports of increasing populations of nuisance macroalgae and epiphytic growth on eelgrass leaves, which may be related to increasing nitrogen concentrations in the Bay. Macroalgae can compete with and smother eelgrass, and heavy epiphyte loads can decrease eelgrass growth, reducing eelgrass biomass and cover.

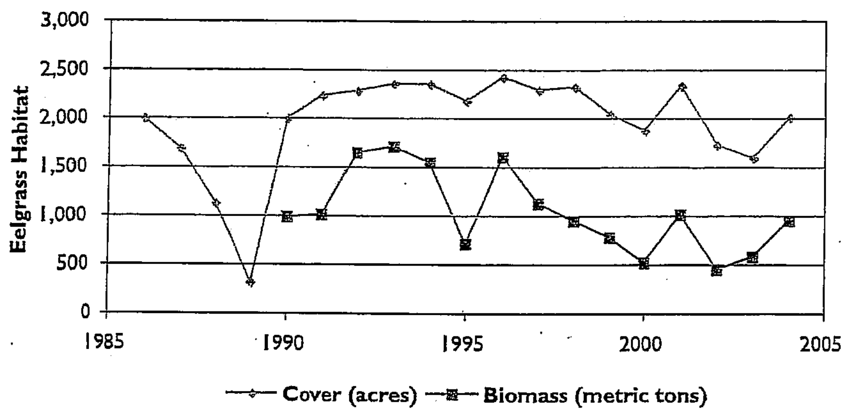
NHEP Goal: Maintain habitats of sufficient size and quality to support populations of naturally occurring plants, animals, and communities.

Eelgrass plays a vital role in the ecology of Great Bay



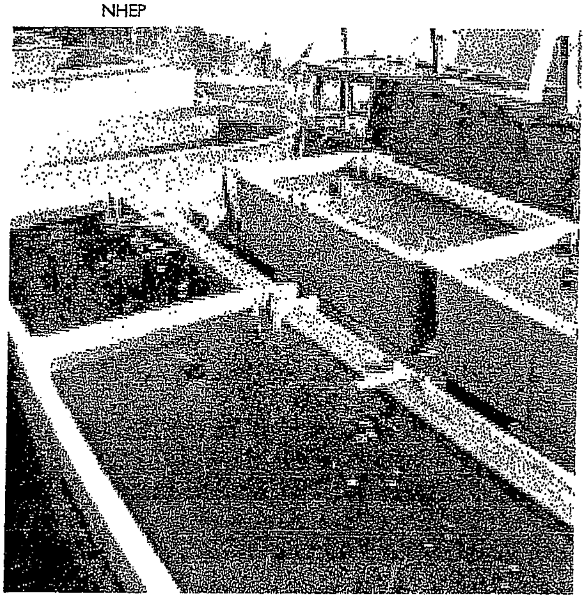
NHEP

Eelgrass cover and biomass in the Great Bay (Figure 17)



Data Source: UNH Seagrass Ecology Group

NHEP



An eelgrass experiment at UNH Jackson Estuarine Laboratory examines the relationship between eelgrass and turbidity

GLOBAL DECLINE OF SEAGRASS

Eelgrass trends observed in New Hampshire mirror trends in seagrass health across the world, although declines may be caused by different factors. SeagrassNet, a global monitoring program initiated in 2001, monitors seagrass at 48 sites in 18 countries. Findings indicate that seagrass is declining at nearly all the sites monitored. Causes of declines include diseases, increased sedimentation from land use disturbance activities, decreased water clarity from water pollution, dredging and other physical disturbances, and many other anthropogenic impacts.

Eelgrass loss (as well as loss of other types of seagrasses) affects water quality because the root systems of plants help stabilize sediments to prevent erosion, and the plants themselves filter nutrients and particulates from the water column. Other species such as shellfish, fish, and waterfowl that depend on these important aquatic habitats for food and shelter are in turn affected by eelgrass loss.

Information about the Global Seagrass Monitoring Network can be found at www.seagrassnet.org.

Are habitats being restored?

YES FOR SALT MARSH, BUT OYSTER AND EELGRASS HABITATS HAVE BEEN RESTORED AT A SLOWER RATE.

Why this is important

Historical data suggests that salt marshes, oyster beds, and eelgrass habitats in New Hampshire's estuaries have been degraded or destroyed over time. Restoration efforts attempt to restore the function of these critical habitats.

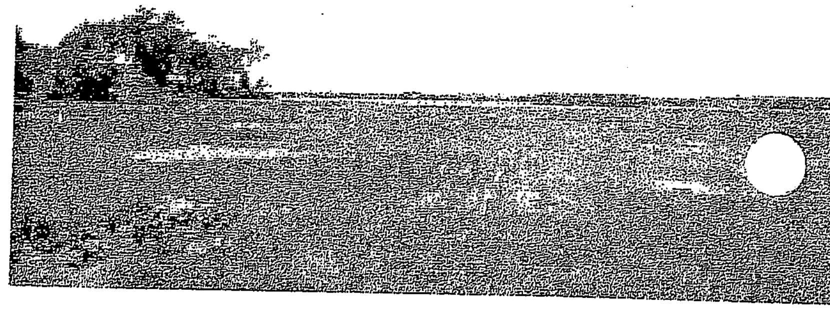
Explanation

There has been significant progress toward the goal of restoring 300 acres of salt marsh by 2010 (Figure 18). The current tally of salt marsh restoration projects by tidal restriction removal since January 1, 2000 is 279 acres (93 percent of the goal). The NH Coastal Program is planning additional salt marsh restoration by tidal restriction removal, which, if completed, would surpass the NHEP goal. This indicator tracks restoration effort in terms of acres for which restoration was attempted. The area of functional habitat created by restoration projects has not been determined and may be lower.

Habitat restoration projects for oyster beds and eelgrass also have been completed, although many additional acres are needed to meet the NHEP management goals. Five oyster restoration projects have been implemented in the Great Bay Estuary and have resulted in a total of 3.18 restored acres of oyster bed (16 percent of the NHEP goal). Since 2000, 1.75 acres of eelgrass restoration projects have been completed (3.5 percent of the goal). As with salt marsh restoration, these indicators track restoration effort in terms of acres for which restoration was attempted. The area of functional habitat created by restoration projects may be lower.

NHEP Goal: Restore 300 acres of salt marsh through tidal restriction removal, 20 acres of oyster beds, and 50 acres of eelgrass beds by 2010.

Restored Pickering Brook salt marsh

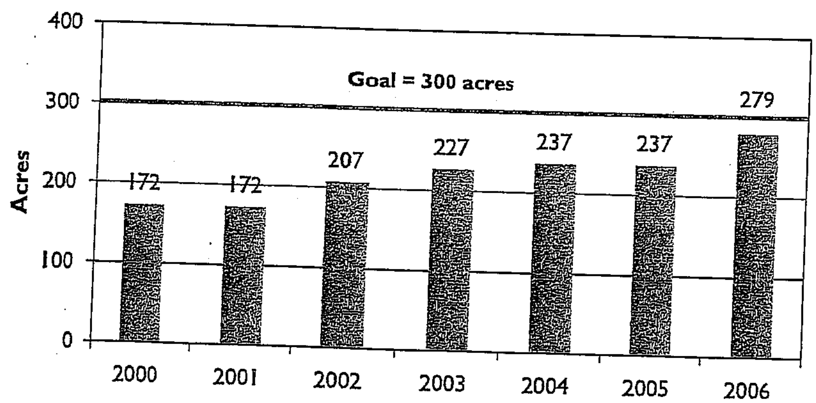


NHEP

HABITAT RESTORATION OPPORTUNITIES

The Great Bay Estuary Restoration Compendium, recently completed by The Nature Conservancy with funding from the NHEP and the NH Coastal Program, identifies ecological restoration opportunities in and around Great Bay. The compendium is the first comprehensive look at restoration priorities in Great Bay that includes multiple habitats and species, such as oyster reefs, soft-shell clam beds, salt marshes, eelgrass, shoreline buffers, and diadromous fish. Sites were identified by comparing historic and current distributions of habitats and species, identifying specific areas of loss, and using models to estimate which of these areas represented realistic restoration opportunities based on current environmental conditions. Final selection of the most promising areas was based on expert review and the potential for multiple habitat projects. The resulting compendium of historic, modern, and desired future conditions also includes information on appropriate restoration techniques. The compendium will be used by the NHEP, NH Coastal Program, and others as a guide for future restoration efforts in the coastal watershed area. The restoration compendium is available on the NHEP website: www.nhep.unh.edu.

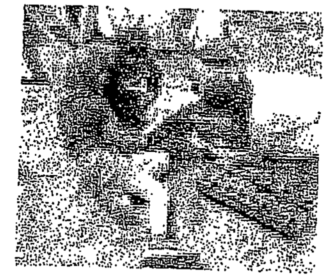
Cumulative area of salt marsh restoration projects (Figure 18)



Data Source: NH Coastal Program

AWCOMIN SALT MARSH RESTORATION PROJECT

A celebration held in April 2006 highlighted five years of work by many organizations, led by the Town of Rye, Natural Resources Conservation Service, and the NH Coastal Program, to restore the 30-acre Awcomin Marsh in Rye, New Hampshire. The marsh was long ago degraded by filling of dredged materials that changed the elevation, hydrology, and plant composition of the marsh. The embattled marsh lacked pools and pannes and was overrun with invasive plants. Restoration of the marsh has occurred in several phases starting in 1991, when the NH Coastal Program and its partners removed old berms and excavated new channels and creeks on the site. The latest restoration effort, which began in 2001, aimed to remove dredge spoils (totaling about 9,000 dump truck loads), recreate the tidal creek system and open water habitat, and restore native vegetation. After more than five years of planning, construction, and revegetation activities, the latest phase of restoration was complete. An ongoing monitoring program organized by the NH Coastal Program tracks changes in salinity, water level, vegetation, and fish communities to assess the long-term success of the restoration effort. A boardwalk and two viewing platforms were installed to provide recreational opportunities and access to this marsh system. In the future, additional restoration work to control invasive species and mosquito habitat may be needed at this site.



NHEP

Third grade students and teac plant switchgrass seedlings for a NHEP-funded revegetation project at Awcomin Marsh

How much of New Hampshire's coastal watershed is covered by impervious surfaces?

In 2005, eight percent of the land area of the watershed was covered by impervious surfaces, and 10 subwatersheds had greater than 10 percent impervious surface cover.

Why this is important

Impervious surfaces such as paved parking lots, roadways, and building roofs increase the pollutant load, sediment load, volume, and velocity of stormwater flowing into the estuaries. Studies conducted in other regions of the country have demonstrated water quality deterioration where impervious surfaces cover greater than 10 percent of the watershed area (CWP, 2003). In 2005 a study in New Hampshire demonstrated the percent of urban land use in stream buffer zones and the percent of impervious surface in a watershed can be used as indicators of stream quality (Deacon et al., 2005).

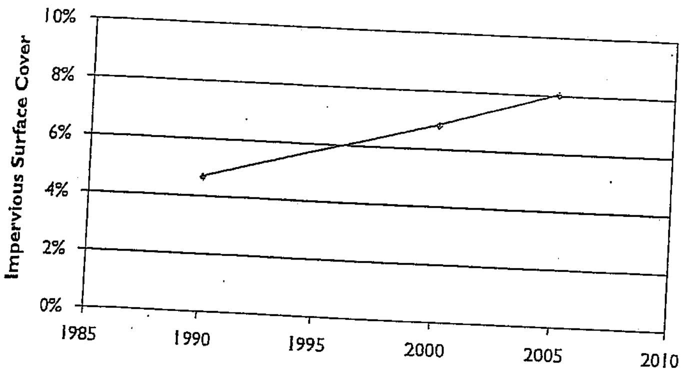
Explanation

Overall, the area of impervious surfaces in the coastal watershed has grown from 24,349 acres in 1990 to 35,503 acres in 2000 to 41,784 acres in 2005. On a percentage basis, 4.7 percent, 6.8 percent, and 8.0 percent of the land area in the watershed was covered by impervious surfaces in 1990, 2000, and 2005, respectively (Figure 19). The number of watersheds with greater than 10 percent impervious surface cover was two in 1990, six in 2000, and 10 in 2005. Between 1990 and 2000, 11,154 acres of impervious surfaces were added to the watershed (1,115 acres per year). Impervious surfaces were added at a slightly higher rate between 2000 and 2005 (1,256 acres per year). All of these summary statistics show that impervious surfaces have been added to the watershed at an average rate of 1,185 acres per year over the past 15 years.

The percent of impervious surfaces in each coastal watershed in 2005 is shown in Figure 20. The watersheds with greater than 10 percent impervious surfaces are along the Atlantic Coast and up the Route 16 corridor along the Salmon Falls River and the Cocheco River. Town-by-town information for 1990, 2000, and 2005 is shown in Figure 21.

NHEP Goal: Keep the coverage of impervious surfaces in coastal subwatersheds less than 10 percent.

Percent of land area covered by impervious surfaces in the coastal watershed in 1990, 2000, and 2005 (Figure 19)



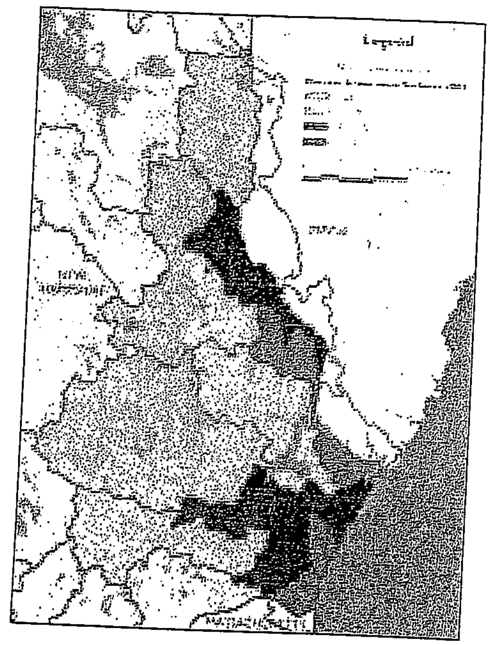
Data Source: UNH Complex Systems Research Center

Percent of land area covered by impervious surface in 1990, 2000, and 2005 (Figure 21)

Town	Land Area (acres)	Percent Imperviousness		
		1990	2000	2005
BARRINGTON	29,719	2.6%	4.0%	4.7%
BRENTWOOD	10,742	5.0%	7.7%	9.5%
BROOKFIELD	14,593	1.0%	1.3%	1.4%
CANDIA	19,342	2.7%	4.1%	4.8%
CHESTER	16,620	2.5%	4.3%	5.1%
DANVILLE	7,439	3.5%	6.0%	7.2%
DEERFIELD	32,587	1.5%	2.4%	3.0%
DOVER	17,094	11.0%	15.4%	18.6%
DURHAM	14,308	4.7%	7.2%	7.7%
EAST KINGSTON	6,319	3.5%	5.3%	7.0%
EPPING	16,468	4.0%	6.5%	7.8%
EXETER	12,553	7.5%	11.0%	12.4%
FARMINGTON	23,221	3.0%	4.2%	4.7%
FREMONT	11,036	3.0%	4.9%	5.9%
GREENLAND	6,780	6.7%	10.5%	12.5%
HAMPTON	8,317	14.2%	19.3%	20.6%
HAMPTON FALLS	7,719	4.4%	6.9%	9.1%
KENSINGTON	7,637	3.2%	5.0%	6.2%
KINGSTON	12,495	5.2%	8.2%	9.7%
LEE	12,680	3.7%	5.8%	6.6%
MADBURY	7,403	3.4%	5.3%	5.3%
MIDDLETON	11,560	1.8%	2.5%	3.0%
MILTON	21,099	2.8%	4.0%	4.7%
NEW CASTLE	504	21.4%	30.7%	33.9%
NEW DURHAM	26,347	1.7%	2.4%	2.8%
NEWFIELDS	4,542	3.1%	5.5%	6.8%
NEWINGTON	5,215	13.2%	18.0%	20.2%
NEWMARKET	8,073	5.9%	8.8%	10.1%
NORTH HAMPTON	8,865	7.3%	10.8%	12.4%
NORTHWOOD	17,976	2.4%	3.4%	4.0%
NOTTINGHAM	29,880	1.5%	2.3%	2.8%
PORTSMOUTH	10,001	21.3%	27.3%	30.5%
RAYMOND	18,448	5.3%	8.0%	9.3%
ROCHESTER	28,331	8.5%	11.7%	13.9%
ROLLINSFORD	4,682	5.7%	8.1%	9.3%
RYE	7,997	7.3%	11.0%	12.8%
SANDOWN	8,889	3.8%	6.1%	7.9%
SEABROOK	5,669	14.1%	21.3%	27.1%
SOMERSWORTH	6,220	12.3%	16.4%	20.2%
STRAFFORD	31,153	1.4%	2.0%	2.3%
STRATHAM	9,672	6.5%	10.1%	12.9%
WAKEFIELD	25,264	3.5%	4.8%	5.6%

Data Source: UNH Complex Systems Research Center

Impervious surface cover in coastal watersheds (Figure 20)



Data Source: UNH Complex Systems Research Center

UNH STORMWATER CENTER

The treatment and management of stormwater becomes increasingly important with the growing amounts of impervious surface cover in New Hampshire's coastal watershed. The UNH Stormwater Center, with support from the Cooperative Institute for Coastal and Estuarine Environmental Technology, serves as a resource to communities and managers for information on stormwater treatment devices and management practices. The Center's field facility tests a dozen different treatment systems, including manufactured devices, conventional structures such as ponds and swales, and newer designs often referred to at "low impact development" technologies such as bioretention systems and gravel wetlands. The Center monitors each treatment type for its ability to remove water pollution constituents typically found in stormwater and control stormwater peak flow and flow volume through storage and/or infiltration. In workshops conducted by UNH at the field site, stormwater managers, regulators, and land use decision-makers view how the structures function first hand, and they review monitoring data collected for each treatment type.

Results from the first year of facility operation indicated low impact development treatment systems typically performed well at removing many pollutants and reducing peak flow. Systems that included infiltration, filtration, biological treatment, and/or storage capacities tended to be the best performers. The most commonly used stormwater treatment and management systems – stone swales – had relatively low performance. The effectiveness of manufactured devices varied, with those that included filtration or infiltration components performing better than those that did not include these components.

For the latest information on the UNH Stormwater Center and its reports, visit www.unh.edu/erg/cstev or www.ciceet.unh.edu.

Is the coastal watershed experiencing "sprawl-type" development?

YES. FROM 1990 AND 2005, LAND CONSUMPTION INCREASED FROM 0.152 TO 0.217 ACRES OF IMPERVIOUS SURFACE PER PERSON.

Why this is important

Increasing rates of land consumption per person is an indicator of sprawl-type development. Undeveloped land is at a premium in New Hampshire's coastal watershed. Accelerated consumption of this land is a threat to the habitats, health, and aesthetic quality of the watershed. Sprawl is a regional issue of concern as population in the Seacoast region continues to increase. If development is poorly planned, it can result in creation of unnecessary impervious surface cover with impacts to water quality, wildlife, and other natural resources.

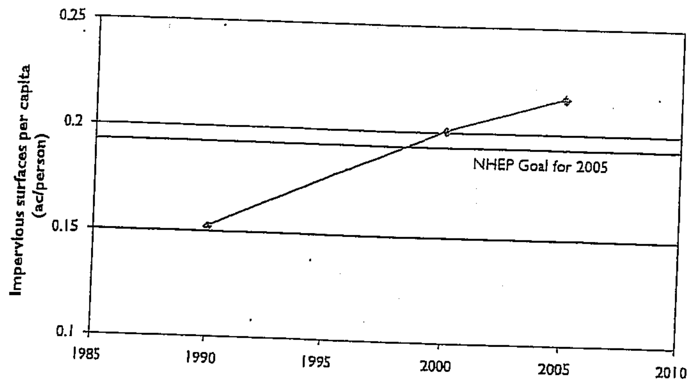
Explanation

Overall, the average imperviousness per capita for the 42 municipalities grew from 0.152 acres per person in 1990 to 0.201 acres per person in 2000 to 0.217 acres per person in 2005 (Figure 22). The average value for 2005 was higher than the average of the NHEP goals for the individual towns (0.193 acres per person). Only 15 of the 42 municipalities met the NHEP goals for imperviousness per capita (Figure 23). These statistics clearly demonstrate that land consumption per person in the coastal watershed is still increasing and that sprawl-type development is still occurring.

While the average values indicate an overall problem with sprawling growth, the imperviousness per capita varied between municipalities (Figure 24). There was a marked difference in imperviousness per capita between municipalities with populations less than 10,000 people (0.207 acres/person) and municipalities with more than 10,000 people (0.120 acres/person). Of the 27 municipalities that did not meet the NHEP goal in 2005, only one was a municipality with greater than 10,000 people (Somersworth). As municipalities approach build out, population growth results in development of smaller lots and in multi-storied buildings which create less impervious surface per person than typical single family homes. The linear relationship between population and imperviousness may only be applicable to smaller towns with abundant undeveloped land.

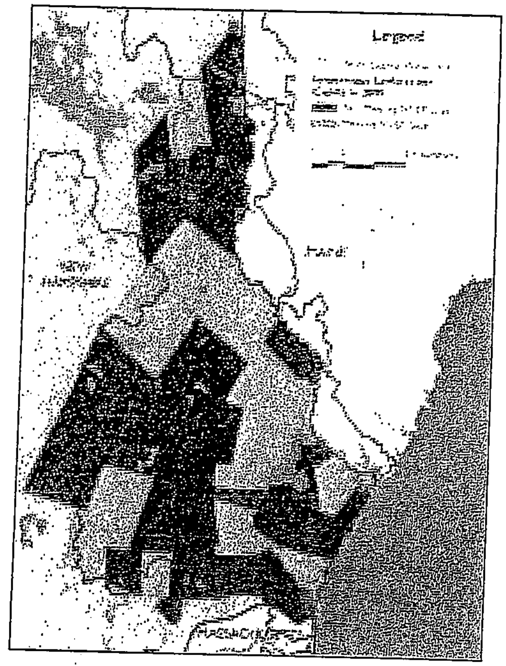
NHEP Goal: New development in coastal watershed towns between 2000 and 2010 should add no more than 0.1 acres of impervious surfaces per new resident.

Average impervious surfaces per capita in coastal municipalities (Figure 22)



Data Source: UNH Complex Systems Research Center

Coastal watershed towns with impervious surfaces per capita greater than NHEP goals (Figure 23)



Data Source: UNH Complex Systems Research Center

Impervious surfaces per capita (Figure 24)

Town	Imperviousness per Capita (ac/person)			
	1990	2000	2005	Goal
BARRINGTON	0.124	0.159	0.172	0.154
BRENTWOOD	0.205	0.259	0.251	0.225
BROOKFIELD	0.269	0.316	0.298	0.296
CANDIA	0.149	0.203	0.225	0.197
CHESTER	0.157	0.190	0.187	0.175
DANVILLE	0.103	0.111	0.121	0.110
DEERFIELD	0.157	0.209	0.231	0.196
DOVER	0.075	0.098	0.110	0.098
DURHAM	0.057	0.081	0.082	0.082
EAST KINGSTON	0.164	0.188	0.222	0.179
EPPING	0.127	0.196	0.218	0.188
EXETER	0.075	0.098	0.107	0.098
FARMINGTON	0.120	0.167	0.167	0.159
FREMONT	0.128	0.153	0.164	0.147
GREENLAND	0.164	0.222	0.248	0.215
HAMPTON	0.096	0.107	0.111	0.107
HAMPTON FALLS	0.227	0.285	0.347	0.273
KENSINGTON	0.149	0.200	0.227	0.191
KINGSTON	0.116	0.174	0.195	0.170
LEE	0.125	0.179	0.193	0.175
MADBURY	0.179	0.261	0.225	0.239
MIDDLETON	0.173	0.197	0.211	0.184
MILTON	0.162	0.215	0.228	0.203
NEW CASTLE	0.129	0.153	0.164	0.152
NEW DURHAM	0.232	0.283	0.299	0.267
NEWFIELDS	0.160	0.162	0.187	0.158
NEWINGTON	0.694	1.214	1.330	1.187
NEWMARKET	0.067	0.088	0.089	0.090
NORTH HAMPTON	0.178	0.225	0.243	0.218
NORTHWOOD	0.136	0.168	0.184	0.163
NOTTINGHAM	0.152	0.187	0.201	0.177
PORTSMOUTH	0.082	0.131	0.145	0.131
RAYMOND	0.112	0.153	0.165	0.150
ROCHESTER	0.090	0.116	0.130	0.115
ROLLINSFORD	0.100	0.144	0.163	0.143
RYE	0.127	0.169	0.194	0.168
SANDOWN	0.083	0.106	0.123	0.105
SEABROOK	0.123	0.152	0.182	0.149
SOMERSWORTH	0.068	0.089	0.106	0.089
STRAFFORD	0.146	0.176	0.183	0.169
STRATHAM	0.127	0.154	0.179	0.149
WAKEFIELD	0.287	0.288	0.299	0.270
AVERAGE	0.152	0.201	0.217	0.193

Data Source: UNH Complex Systems Research Center

COMMUNITIES PROTECTING NATURAL RESOURCES

Sprawling patterns of growth, which are typically associated with increases in impervious surfaces, affect water quality and other natural resources. A study conducted by the US Geological Survey and NH Coastal Program in the coastal watershed found that water quality parameters and macroinvertebrate populations were negatively impacted by various indicators of development. The amounts of urban land use in stream buffer areas and the amounts of impervious surface in subwatersheds have a direct bearing on water quality.

Assistance is available for communities to develop and implement plans to protect natural resources in the face of increasing development and growth. The Natural Resources Outreach Coalition (NROC) works with two to three communities each year to help identify important natural resources and facilitate town-initiated activities to protect them. As of 2006, over 15 towns in the coastal watershed have benefited from the NROC assistance. Community-initiated projects have resulted in improved ordinances, land protection projects, open space plans, successful town votes for land conservation funding, habitat inventories, and increased involvement of citizens in conservation activities.

Another resource is the NHEP's Community Technical Assistance Program (CTAP) that provides consulting services to communities to assist with regulatory and nonregulatory approaches to natural resources protection. Assistance is available for projects related to land conservation planning, stormwater management, and buffer protections. During the first year of this program, eleven communities have received customized technical assistance. For information on NROC or CTAP, contact the NHEP at Contact.NHEP @unh.edu or visit www.nhep.unh.edu.

How much of the coastal watershed is protected from development?

CURRENTLY, 54,622 ACRES IN THE WATERSHED ARE PROTECTED, WHICH AMOUNTS TO 10.7 PERCENT OF THE LAND AREA.

Why this is important

Development of land for residential, commercial, industrial, and other uses can eliminate or disrupt habitats and increase stormwater runoff and other sources of water pollution. Permanently protecting key areas from development will maintain the ecosystem benefits provided by healthy, natural landscapes.

Explanation

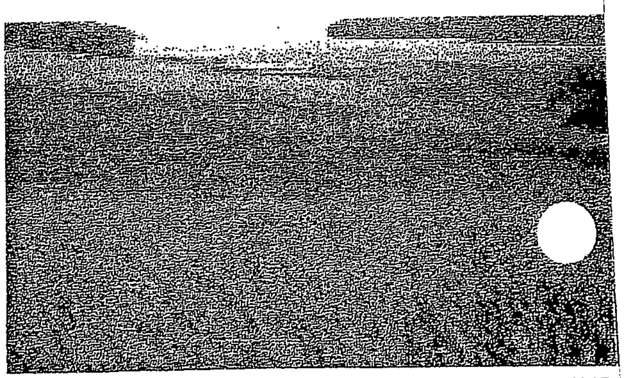
As of 2005, there were 54,622 acres of protected land in New Hampshire's coastal watershed, which represented 10.7 percent of the entire watershed land area (Figure 25). Over the past three years, 12,037 acres in the coastal watershed have been permanently protected from development (4,012 acres per year on average). In order to reach the NHEP goal of protecting 15 percent of the watershed land area by 2010, an additional 21,790 acres need to be protected in the watershed. The rate of land protection will need to increase in order to meet the NHEP goal.

The percentage of land area that is protected in each town is shown in Figure 26. This map shows that progress toward the NHEP goals has been good in the towns around Great Bay, near the coast, and in the vicinity of the Bear Brook and Pawtuckaway State Parks. In contrast, there is a lower percentage of protected land in the Salmon Falls River and Cocheco River watersheds.

Many municipalities, land trusts, and conservation organizations are working to protect lands from rapidly increasing development. One especially successful effort is guided by the Great Bay Resource Protection Partnership (GBRPP), which is a collaborative group of nine conservation organization and agencies. As of December 2005, the GBRPP has facilitated the protection of over 7,000 acres of land in the Great Bay region.

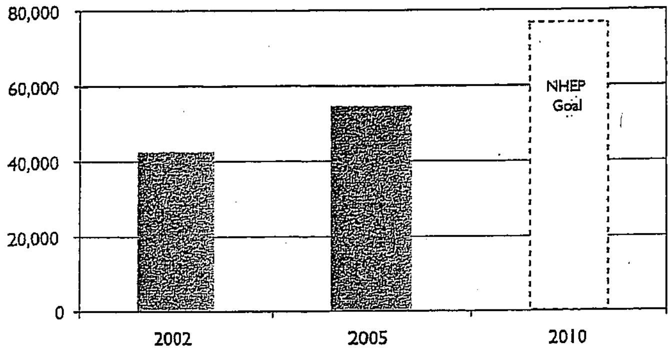
NHEP Goal: Increase the acres of protected private and public lands from baseline levels to 15 percent by 2010.

Protected by The Nature Conservancy, Lubberland Creek Preserve covers 120 acres adjacent to Great Bay



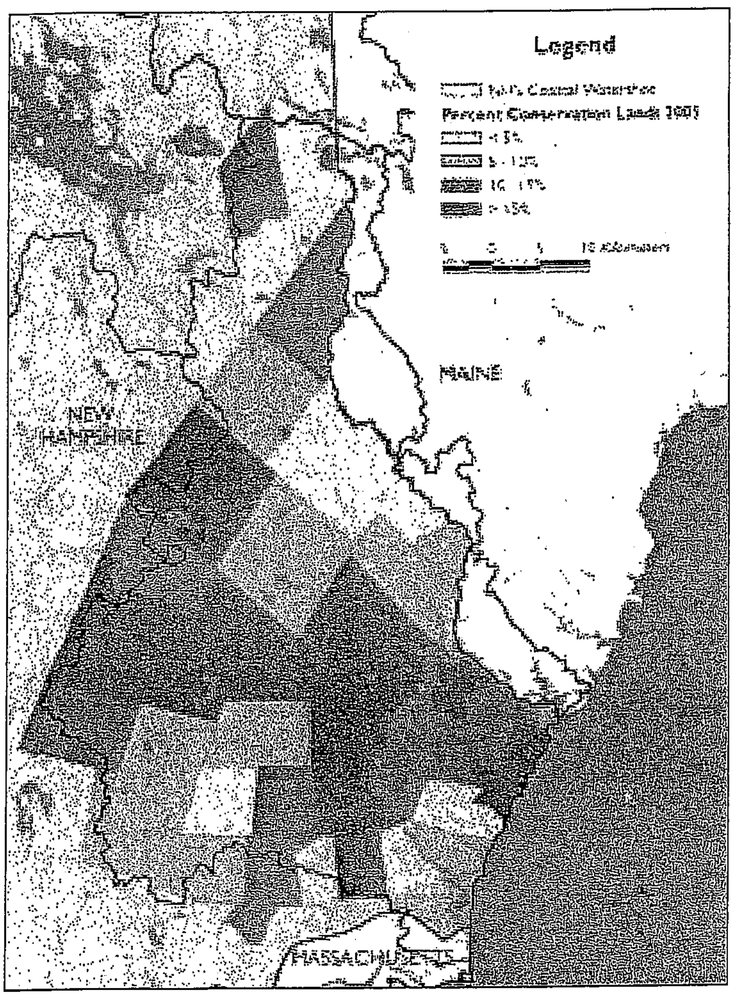
TNC

Conservation lands in the coastal watershed (Figure 25)



Data Source: UNH Complex Systems Research Center

Coverage of conservation lands in municipalities in the coastal watershed (Figure 26)



Data Source: UNH Complex Systems Research Center

LAND CONSERVATION PLAN FOR NEW HAMPSHIRE'S COASTAL WATERSHEDS

To maintain healthy coastal ecosystems, ecologically valuable land needs to be protected from development. The recently completed Land Conservation Plan for New Hampshire's Coastal Watersheds identifies 75 conservation focus areas totaling over 230,000 acres that are key targets for land protection activities. The areas identified in the plan are important for the protection and maintenance of ecosystem functions and ecological integrity throughout the coastal watershed. The conservation focus areas were selected for their importance in protecting water quality and aquatic resources, promoting large forested habitat blocks, and supporting critical habitats and species that are valued in the seacoast region. The plan is intended to serve as a scientifically defensible guide to support habitat protection activities – both through traditional conservation approaches (e.g., fee ownership and conservation easements) and regulatory approaches that limit development in high priority areas and encourage conservation practices. The NH Coastal Program will use the plan as the foundation for the State's Coastal and Estuarine Land Conservation Program (CELCP). For more information on the plan, go to www.nhep.unh.edu.

ACKNOWLEDGEMENTS

The creation of the 2006 State of the Estuaries Report would not have been possible without the collaborative work of many partnering organizations and committed individuals. Special recognition goes to the following organizations for sharing data and coordinating efforts to help understand the status of New Hampshire's estuaries:

FPL Energy Seabrook Station
Great Bay National Estuarine Research Reserve
Gulf of Maine Council Gulfwatch Program
New Hampshire Coastal Program
New Hampshire Department of Environmental Services
New Hampshire Department of Transportation
New Hampshire Fish and Game Department
New Hampshire Natural Heritage Bureau
Society for the Protection of New Hampshire Forests
University of New Hampshire
US Environmental Protection Agency

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Tom Gillick, Town of Hampton
Jennifer Hunter, New Hampshire Estuaries Project
Pat Kelley, Wentworth by the Sea Marina
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Theresa Walker, Rockingham Planning Commission
Peter Wellenberger, Great Bay National Estuarine Research Reserve
Mark Zankel, The Nature Conservancy

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Phil Trowbridge, New Hampshire Estuaries Project

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ATTACHMENT E

UNIVERSITY of NEW HAMPSHIRE

Jackson Estuarine Laboratory, 85 Adams Point Road, Durham, New Hampshire 03824 Tel. 603-862-5134, Fax. 603-862-1101

To: Thomas F. Irwin,
Conservation Law Foundation

Regarding the waiver that has been requested by the City of Portsmouth to avoid upgrading the sewage treatment plant to secondary treatment, I would like to provide the following information. I am a Research Professor at the Jackson Estuarine Laboratory, University of New Hampshire and have worked on the Great Bay Estuary for more than 20 years.

1) Despite the fact that the Great Bay Estuary appears pristine, numerous signs of ecosystem degradation are evident throughout the estuary. The Great Bay Estuary is a stressed ecosystem as a result of high loading of nitrogen into the estuary from many sewage treatment plants and from non-point sources as well.
2) The Portsmouth sewage treatment plant is the largest input of nitrogen to the estuary, and, despite the discharge location between Pierce and Seavey Islands, half the time, the sewage input goes up the estuary rather than seaward, due to the strong tidal influence.
3) When nitrogen from the Portsmouth plant is flushed into the Great Bay Estuary, it enriches the waters, producing excess growth of macroalgae. The production of these nuisance algae are detrimental to the overall health of the estuarine ecosystem: as a result of nitrogen loading, estuarine systems are known to become eutrophic, as evidenced in Chesapeake Bay, Boston Harbor, and Waquoit Bay on Cape Cod. Under eutrophic conditions, the estuarine ecosystem is disrupted, low oxygen events occur (anoxia), fish kills occur, eelgrass beds are lost, and many functions of the estuary are lost.
4) When nitrogen from the Portsmouth plant is flushed out of Portsmouth Harbor seaward, it forms a plume which moves down the coast to the south along the New Hampshire beaches, where again it stimulates the excessive growth of nuisance macroalgae, as described in <u>Popular Science</u> (2002): "The Green Globs".
5) The "State of the Estuary" report (2003) produced by the New Hampshire Estuaries Project (NHEP) documents progressive increases in nitrate + nitrite in the estuary from 1994 through 2002. This alarming increase of nitrogen levels in the estuary is accompanied by more abundant nuisance algae growth throughout the estuary, an indicator of eutrophication from nutrient over-enrichment.
6) The use of a newly developed Nutrient Pollution Indicator (NPI) (Short et al. 2004) clearly demonstrates elevated nitrogen levels in the area of the Portsmouth sewage treatment plant. From these studies, it is clear that the primary treated sewage from the Portsmouth plant makes a detectable contribution to the degradation of the Great Bay Estuary.

The bottom line: the Great Bay Estuary is suffering from excess nitrogen inputs, with contributions from the Portsmouth sewage treatment plant representing a large portion of the excess. Permitting waiver renewal for secondary treatment will increase the nutrient problem and possibly lead to the kind of ecological disruption that has occurred in other estuaries.

Sincerely,

Frederick T. Short, Ph.D.
Research Professor,
Department of Natural Resources
fred.short@unh.edu

ATTACHMENT F

UNITED STATES OF AMERICA

ENVIRONMENTAL PROTECTION AGENCY

BOSTON REGION

In the Matter of:

PUBLIC HEARING:

RE: CITY OF PORTSMOUTH, NEW HAMPSHIRE
PUBLICLY OWNED TREATMENT WORKS,
APPLICATION FOR SECTION 301(H)
VARIANCE FROM THE SECONDARY
TREATMENT REQUIREMENTS OF THE
CLEAN WATER ACT

City Hall
Portsmouth, New Hampshire

Monday
May 9. 2005

The above entitled matter came on for hearing, pursuant to Notice at 7:00 p.m.

BEFORE: DAVID M. WEBSTER
DAMIEN HOULIHAN
New Hampshire NPDES Permit Section
Environmental Protection Agency
One Congress Street
Boston, MA 02114

GEORGE BERLANDI
NH Department of Environmental Services

national goal would be that wherever obtainable an interim goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife, and provide for recreation in and on the water be achieved by July 1st, 1983.

Well, when I think about the Pierce Island water treatment plant, I think about the fact that there's a tidal flow and that tidal flow carries some of that effluent down to New Castle, where there's a public beach. Our area children go there. What concerns me is that we're getting bad water there, essentially, that these children are playing in. And granting another waiver would allow this problem to continue.

The city claims that this would cost $30 million per year, and goes on to discuss the aesthetics of a secondary treatment facility, none of these which are in consideration in regards to the Clean Water Act and granting waivers. What is a consideration is recreation, and it concerns me greatly that this is going to be allowed in an area where children frequent the beaches. And I think that it's up to the EPA to make sure that the town and the city becomes in compliance with what is a Clean Water Act.

Thank you.

MR. WEBSTER: Thank you very much.

I next call on Dr. Frederick Short.

DR. SHORT: Thank you. My name is Fred Short. I'm a research professor at the University of New Hampshire, based at the Jackson History & Laboratory. I wanted to speak against the waiver and particularly about the nitrogen issue in the bay.

The Great Bay estuary is viewed as a pristine system and the many places you can view the estuary, it looks beautiful. It's always pristine. But under the waters of the estuary, the system is in trouble. There is increasing evidence of excessive nitrogen building up in the estuary and it's quite well-documented.

As other people have mentioned, the sources of the nitrogen have been looked into and the Portsmouth sewage treatment plant is determined to be the largest source of nitrogen into the estuary. Now they will say that when the tide is running out, that all goes downstream, but the other half of the time it all goes upstream, and it's not hard to figure that those nutrients get up into the upper part of the estuary, as well.

I mean, the salt that makes Great Bay 20 to 25 part per thousand salinity comes from the ocean and works its way up into the bay, so certainly the nutrients are not flushed out of the estuary. And those that are flushed out go into the coastal zone and go down the shore or into a little harbor, and I believe are responsible for the excess of algae that's been documented.

If you remember the green balls or the green globs that were found two or three years ago on the beaches in Hampton, those large productions of seaweed are a result of excess nutrient inputs, and I think that's evidence of the plume that comes out of the Piscataqua River and Portsmouth Harbor.

Increasing nitrogen levels in an estuary are a problem because it increases gradually and suddenly -- all of a sudden you get a change in the system, a dynamic turnover in the system. And the prime example of that is Chesapeake Bay, where in the 1980s the Chesapeake Bay estuary ecosystem collapsed. It lost its eelgrass, it lost its blue crabs, its oysters, because the system was too heavily loaded with nitrogen and the system fell apart. And I'm concerned at the levels of nitrogen that we're seeing here in the Great Bay estuary.

Being a professor, I brought my references. The State of New Hampshire put out the state of the estuary report in 2003 and he shows a significant increase in nitrate levels in the Great Bay estuary. And I looked up those nitrogen levels and compared them to what the levels were in Chesapeake Bay in the 1980s, at the time of the collapse, and we are as high or higher than the levels were in Chesapeake Bay, so I think that's a concern.

And there's other evidence. The EPA put out a guide to the Gulf of Maine, and one of the things it lists is inorganic nitrogen levels; that is, the levels of nitrogen in the water, and it shows the coastline from Massachusetts all the way across the coast of Maine with green, yellow and white dots for different levels of pollution, nutrient input, and the Great Bay estuary is the only site that has red dots, aside from Boston Harbor. Again, another line of evidence suggesting that there is a problem.

Even Great Bay Matters put out by the Great Bay Estuary & Research Reserve has an article talking about the mysterious green algae that's appearing more and more on the shores of the bay. Green algae is an indicator. It only grows because there's excess nitrogen around. So I think the system is building up, increasing amounts of nitrogen.

Dr. Art Mathison, who contributed a letter also talked about other seaweeds that are called nuisance seaweeds that develop under eutrophication conditions. So I think we're in danger of upsetting the balance in the Great Bay estuary and we need to pay a lot of attention to that.

In that regard, over the last four years, I've developed an environmental indicator, which I call a nutrient pollution indicator, and it uses eelgrass, which is one of our local species, to detect levels of nitrogen in the system, because eelgrass grows in the water and it integrates the water that goes by, and we tested this all the way up the estuary. And as you could imagine, when you get close to the rivers coming in, you have higher levels of nitrogen. As you come down the estuary, those levels drop down until you get in Portsmouth Harbor, and then after you get by the New Hampshire Port Authority, levels start to go up, again, and they stay up until you get beyond Seavey Island and out to Portsmouth Harbor.

So what that's saying is that we're detecting higher levels, elevated levels of nitrogen in the vicinity of the Portsmouth sewage treatment discharge. So it is having an effect on the system and I think it is a system under stress.

Thank you.

MR. WEBSTER: Thank you, Dr. Short.

I next call on Lee Roseberry.

MR. ROSEBERRY: Good evening, gentlemen. I'm Lee Roseberry, Portsmouth resident, New Hampshire certified wastewater treatment plant operator, former 15-year employee of the City of Portsmouth wastewater treatment plant.

I've brought to the attention to the City of Portsmouth, to NPDES and to US EPA some questions concerning the reporting of discharge incidents in which I was personally involved, and I would like to ask respectfully

ATTACHMENT G

ELSEVIER

Aquatic Botany 78 (2004) 197–216

Aquatic botany

www.elsevier.com/locate/aquabot

Development of a nutrient pollution indicator using the seagrass, *Zostera marina*, along nutrient gradients in three New England estuaries

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Received 13 June 2001; received in revised form 20 August 2003; accepted 15 September 2003

Abstract

Worldwide, seagrasses provide important habitats in coastal ecosystems, but seagrass meadows are often degraded or destroyed by cultural eutrophication. Presently, there are no available tools for early assessment of nutrient over-enrichment; direct measurements of water column nutrients are ineffective since the nutrients typical of early enrichment are rapidly taken up by plants within the ecosystem. We investigated whether, in a gradient of nutrient availability but prior to actual habitat loss, eelgrass (*Zostera marina* L.) plant morphology and tissue nutrients might reflect environmental nutrient availability. Eelgrass responses to nitrogen along estuarine gradients were assessed; two of these plant responses were combined to create an early indicator of nutrient over-enrichment. Eelgrass plant morphology and leaf tissue nitrogen (N) were measured along nutrient gradients in three New England estuaries: Great Bay Estuary (NH), Narragansett Bay (RI) and Waquoit Bay (MA). Eelgrass leaf N was significantly higher in up-estuary sampling stations than stations down-estuary, reflecting environmental nitrogen gradients. Leaf N content showed high variance, however, limiting its ability to discriminate the early stages of eutrophication. To find a stronger indicator, plant morphological characteristics such as number of leaves per shoot, blade width, and leaf and sheath length were examined, but they only weakly correlated with leaf tissue N. Area normalized leaf mass (mg dry weight cm^{-2}), however, exhibited a strong and consistently negative relationship with leaf tissue N and a significant response to the estuarine nutrient gradients. We found the ratio of leaf N to leaf mass to be a more sensitive and consistent indicator of early

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E-mail address: fred.short@unh.edu (F.T. Short).

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eutrophication than either characteristic alone. We suggest the use of this ratio as a nutrient pollution indicator (NPI).

Keywords: Seagrass; *Zostera marina*; Eelgrass; Nutrients; Nitrogen; Eutrophication; Indicator; Estuary; New England

1. Introduction

Significant declines in seagrass coverage have been reported from many coastal areas (Short and Wyllie-Echeverria, 1996), and the declines are usually related to human activities (Kemp et al., 1983; Cambridge and McComb, 1984; Short and Burdick, 1996; Burdick and Short, 1999; Udy et al., 1999). Estuarine and coastal ecosystems receive increasing amounts of nutrients as a consequence of anthropogenic loading (Valiela et al., 1992; Short and Burdick, 1996; Tomasko et al., 1996; McMahon and Walker, 1998). Increased nutrient loading is widely acknowledged to impact the structure and function of coastal ecosystems (Valiela et al., 1990; Lapointe et al., 1994).

Nutrient over-enrichment leads to nuisance algal blooms, reduced dissolved oxygen in the water column, and decreased fish stocks (Nixon et al., 1986; Taylor et al., 1999; Deegan et al., 2002). Increased nutrient inputs to the water column can also adversely affect seagrass survival and production through stimulation of growth in phytoplankton, epiphyte and macroalgal communities (Harlin and Thorne-Miller, 1981; Short, 1987; Short et al., 1995). Stimulation of competing primary producers caused by water column nutrient enrichment leads to reduction of light available to seagrasses and often to their demise (Harlin and Thorne-Miller, 1981; Van Montfrans et al., 1984; Borum, 1985; Tomasko and Lapointe, 1991; Van Lent et al., 1995).

Because of the harmful effects of nutrient over-enrichment on estuarine and coastal ecosystems, early detection of eutrophication is critical for management. In New England, eutrophication results from nitrogen over-enrichment, as estuarine systems in this region are nitrogen limited (Ryther and Dunstan, 1971); detection of eutrophication requires focus on nitrogen. Direct measurement of in situ nitrogen concentrations to estimate eutrophication is ineffective, however, as estuarine conditions both dilute and dissipate nitrogen loading through tidal and current action as well as microbial and plant uptake. Since phytoplankton and submerged macrophytes can remove nitrogen from the water column rapidly (Morgan and Simpson, 1981; Short and McRoy, 1984; Stapel et al., 1996; Terrados and Williams, 1997; Lee and Dunton, 1999b), over-enrichment of coastal ecosystems rarely can be detected by direct measurements of water column nitrogen concentrations. One of the general indicators of nitrogen over-enrichment in temperate estuarine and coastal ecosystems has been eelgrass (*Zostera marina* L.) die-off and a concomitant increase in algal competitors, but by the time this occurs, ecosystem function has been severely disrupted (Kemp et al., 1983; Orth and Moore, 1983; Short et al., 1995; Short and Burdick, 1996; Short et al., 1996). Managers of coastal environments would benefit from an early indicator of over-enrichment and eutrophication.

Seagrasses respond to nitrogen enrichment both physiologically and morphologically (Burkholder et al., 1992, 1994; Short et al., 1995; Taylor et al., 1995; Tomasko et al., 1996; Udy and Dennison, 1997; Udy et al., 1999). Increased tissue N as a result of N enrichment has been reported for seagrasses (Bulthuis and Woelkerling, 1981; Harlin and Thorne-Miller, 1981; Short, 1987; Duarte, 1990; Bulthuis et al., 1992; Erftemeijer et al., 1994; Alcoverro et al., 1997; Udy and Dennison, 1997; Lee and Dunton, 1999a). Additionally, seagrasses from low-nutrient environments have significantly higher C:N and C:P ratios than plants growing in high nutrient conditions (Atkinson and Smith, 1983; Duarte, 1990; Short et al., 1990; Lee and Dunton, 1999a). Since increased external nutrient concentrations result in increased seagrass tissue nutrient content, we hypothesized that the tissue nitrogen content of eelgrass could contribute to an indicator of early over-enrichment.

Seagrass morphology and growth are strongly linked to available nutrient resources. Short (1983) reported a strong correlation between sediment N and eelgrass leaf morphology. Plants characterized by short and narrow leaves grew in low nitrogen sediment, while plants exhibiting long, wide leaves were found in high nitrogen sediments. Seagrass morphological characteristics such as shoot height and blade width also respond to changes in nutrient loading (Short, 1987; Udy and Dennison, 1997; Lee and Dunton, 2000), but they are influenced by other environmental factors such as light availability, current and wave strength, and tidal exposure.

Eelgrass leaf tissue N and plant morphology were measured along nitrogen gradients in Great Bay Estuary (NH), Narragansett Bay (RI) and Waquoit Bay (MA), USA to correlate eelgrass responses to levels of N exposure. To evaluate the geographic consistency of our results, eelgrass physiological and morphological responses were compared among the three estuarine systems. Many eelgrass morphological characteristics were then evaluated to identify a measure that, in combination with leaf N, would form a robust nutrient pollution indicator (NPI).

2. Materials and methods

2.1. Study sites

The study was conducted in Great Bay Estuary (New Hampshire; 43°05′N, 70°50′W), Narragansett Bay (Rhode Island; 41°35′N, 71°20′W), and Waquoit Bay (Massachusetts; 41°35′N, 70°30′W) along the New England coast, USA (Fig. 1). Twenty sampling stations in the Great Bay Estuary, seven in Narragansett Bay, and five in Waquoit Bay were located from the mouth of each estuary to upper estuarine embayments. Water column dissolved inorganic nitrogen (DIN) concentrations in Great Bay Estuary and Narragansett Bay were low in down-estuary locations and high up-estuary (Short et al., 1993). Pore water ammonium concentrations were generally greatest in Great Bay Estuary, though the ammonium regeneration rate was highest in Narragansett Bay sediments. Up-estuary, both Waquoit Bay and Narragansett Bay showed poor water clarity.

Of the three, Great Bay Estuary had the greatest tidal range (>3 m). Water in the upper part of Great Bay Estuary was well mixed and had consistently lower salinities and higher summer temperatures than down-estuary in Little Bay and the Piscataqua River (Swift

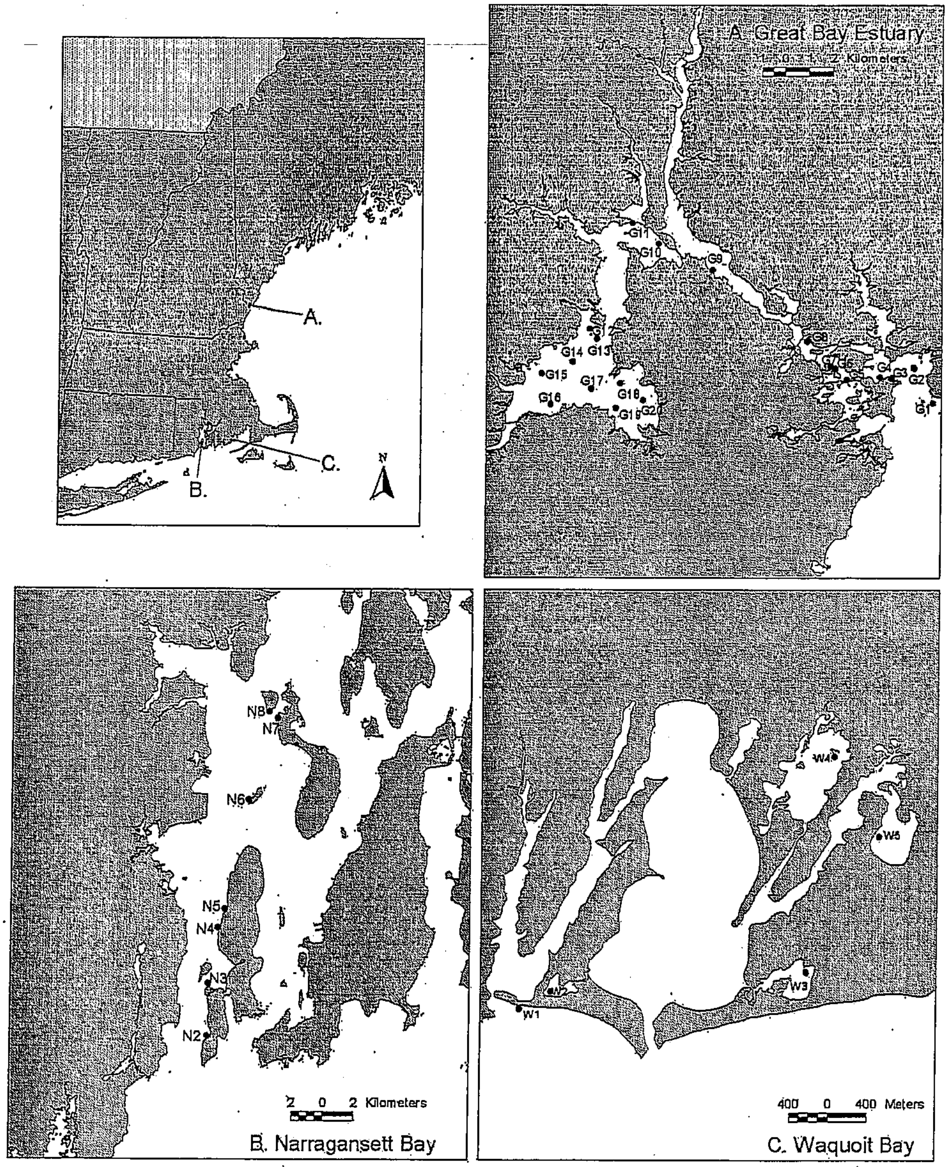

Fig. 1. Location of the three New England (USA) estuaries investigated. Study sites in Great Bay Estuary, New Hampshire (A), Narragansett Bay, Rhode Island (B) and Waquoit Bay, Massachusetts (C). Twenty sampling stations in Great Bay Estuary, seven in Narragansett Bay and five in Waquoit Bay were located from the mouth of each estuary to up-estuary.

and Brown, 1983; Short et al., 1986). Narragansett Bay had a greater tidal range than Waquoit Bay (1.0 m versus 0.3 m), with a small diurnal component (Short et al., 1993). Salinities were less variable in Narragansett Bay (29–31‰) than in the other two estuaries. Major oscillations of eelgrass populations in the Great Bay Estuary have been linked not to pollution or increased nutrient loading but to outbreaks of wasting disease (Short et al., 1986; Burdick et al., 1993). Eelgrass meadows in Narragansett Bay have exhibited relatively high indices of wasting disease in the past, while Waquoit Bay eelgrass populations have had consistently low levels of infection by wasting disease. However, epiphytes and macroalgal and phytoplankton blooms have covered and eliminated most of the eelgrass beds that once existed in Waquoit Bay; the gradient measured in Waquoit Bay ranged from oligotrophic outside the Bay to elevated levels of nutrient loading in various sub-estuaries (Short and Burdick, 1996). The upper parts of Narragansett Bay have been exposed to very high nutrient loads for decades (Nixon and Pilson, 1983); no eelgrass exists in the uppermost reaches of the bay.

2.2. *Plant collection and morphological measurements*

Ten mature terminal eelgrass shoots were collected individually from a boat using a sampling hook at each sampling station during June 1998 in Waquoit Bay and September 1999 in Great Bay Estuary and Narragansett Bay. Sheath length was measured to the nearest 1.0 mm from the meristem to the top of the outermost intact sheath. Shoot height was measured to the nearest 1.0 mm and the width of the longest leaf was measured to the nearest 0.2 mm. The number of leaves per shoot was counted. All epiphytes were carefully scraped from the longest intact leaf using a razor blade, placed onto a pre-weighed glass fiber filter, and dried at 60 °C to a constant weight. Epiphyte biomass was quantified on a leaf area basis (mg dry weight epiphyte cm^{-2} leaf). Wasting Index was measured as a percentage of diseased area for each leaf and then averaged for each shoot (Burdick et al., 1993).

We measured area normalized leaf mass, which we refer to simply as "leaf mass" (mg dry weight cm^{-2} leaf area), a weight per area of plant tissue similar to the "leaf weight per leaf area" of Olesen and Sand-Jensen (1993) and the inverse of specific leaf area (SLA) used by Olesen et al. (2002). Leaf mass was determined on the second and third youngest leaves of each shoot. All epiphytes were removed from these leaves; six 10 cm long sections of constant width were cut from the leaves to obtain samples of mature leaf tissue. The cleaned leaf sections were dried at 60 °C to constant weight and leaf mass was quantified.

2.2.1. *Leaf C and N content*

Leaf tissue C and N content were determined from tissues of the second and third youngest leaves for each shoot. Dried leaf material was ground to pass through a 40 mesh screen in a Wiley mill, and 2–3 mg of ground tissue was used to determine leaf C and N content using an elemental analyzer (Carlo Erba Nitrogen Analyzer 1500); molar C:N was calculated.

2.2.2. *Statistics*

All values are reported as means ± 1 standard error (S.E.). Data were tested for normality and homogeneity of variance to meet the assumptions of parametric statistics. Significant differences in seagrass morphological parameters and tissue nutrient content among sampling stations within an estuary were tested using 1-way ANOVA, as were significant differences in parameters among the three estuarine systems. When a significant difference was observed, the means were analyzed by Tukey's multiple comparison test to determine where the significant differences occurred within and among estuarine systems. Slopes of linear regressions between variables were tested for significance.

3. Results

3.1. Leaf N content

Eelgrass leaf N content in the Great Bay Estuary ranged from 2.1 to 3.5% dry weight, and was significantly ($P < 0.001$) higher in up-estuary stations than in those seaward (Fig. 2A). Sampling stations at the mouth of the estuary, where water is well mixed with ocean water, had the lowest plant tissue N content. Eelgrass leaf C content in the Great Bay Estuary also differed significantly ($P < 0.001$) among sampling stations, but there was no discernable pattern (Table 1). The C:N in eelgrass leaf tissue exhibited an inverse trend to leaf N content and was higher in down-estuary stations and lower in up-estuary stations (Fig. 3A).

In Narragansett Bay, eelgrass leaf N content varied little, from 2.0 to 2.3% (Fig. 2B), and differences between stations were not significant ($P = 0.072$). Leaf C content was lower in stations down-estuary than up-estuary and was significantly ($P < 0.001$) different among sampling stations (Table 1). The C:N was not significantly ($P = 0.41$) different among the Narragansett Bay stations (Fig. 3B).

In Waquoit Bay, eelgrass leaf N content ranged from 1.6 to 2.4% and was significantly ($P < 0.001$) lower at the two stations located outside (W1) and just inside (W2) the mouth of the estuary (Fig. 2C). The C:N decreased significantly ($P < 0.001$) along the gradient in Waquoit Bay (Fig. 3C), showing a similar, but inverse, trend to leaf N content. Leaf C content showed significant differences between sampling stations but no clear trend (Table 1).

Comparing the three estuaries, mean values of eelgrass leaf N content (Fig. 2) were significantly ($P < 0.001$) higher in the Great Bay Estuary (2.8% N) than in Narragansett Bay (2.1% N) and Waquoit Bay (2.0% N). Mean C content (Table 1) was significantly ($P < 0.001$) lower in Narragansett Bay (35.5% C) than in the Great Bay Estuary (37.9% C) and Waquoit Bay (37.8% C). The C:N (Fig. 3) was highest in Waquoit Bay (22.6), intermediate in Narragansett Bay (19.5), and lowest in the Great Bay Estuary (16.4).

3.2. Leaf mass and plant morphology

Leaf mass in the Great Bay Estuary varied between 1.7 and 4.8 mg dry wt. cm^{-2} leaf area, and was significantly ($P < 0.001$) higher seaward than at up-estuary stations (Fig. 4A). In Narragansett Bay and Waquoit Bay, leaf mass was also significantly ($P < 0.001$) higher seaward (Fig. 4B and C). Mean leaf mass varied among the three estuaries and was highest in Narragansett Bay (5.1 mg cm^{-2}) and lowest in Great Bay Estuary (3.0 mg cm^{-2}; Fig. 4A and B).

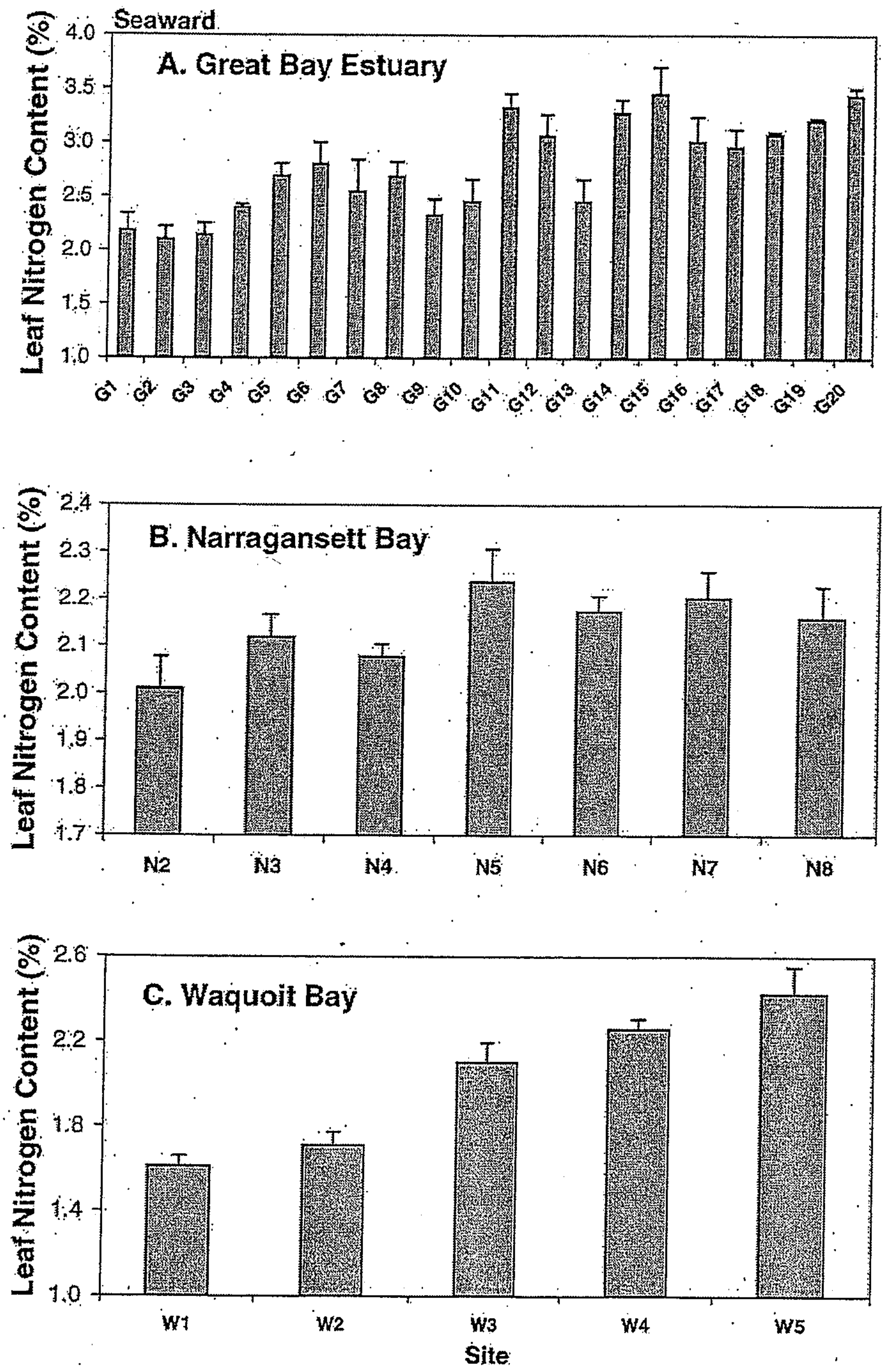

Fig. 2. Leaf nitrogen content of eelgrass along estuarine gradients in Great Bay Estuary (A), Narragansett Bay (B), and Waquoit Bay (C).

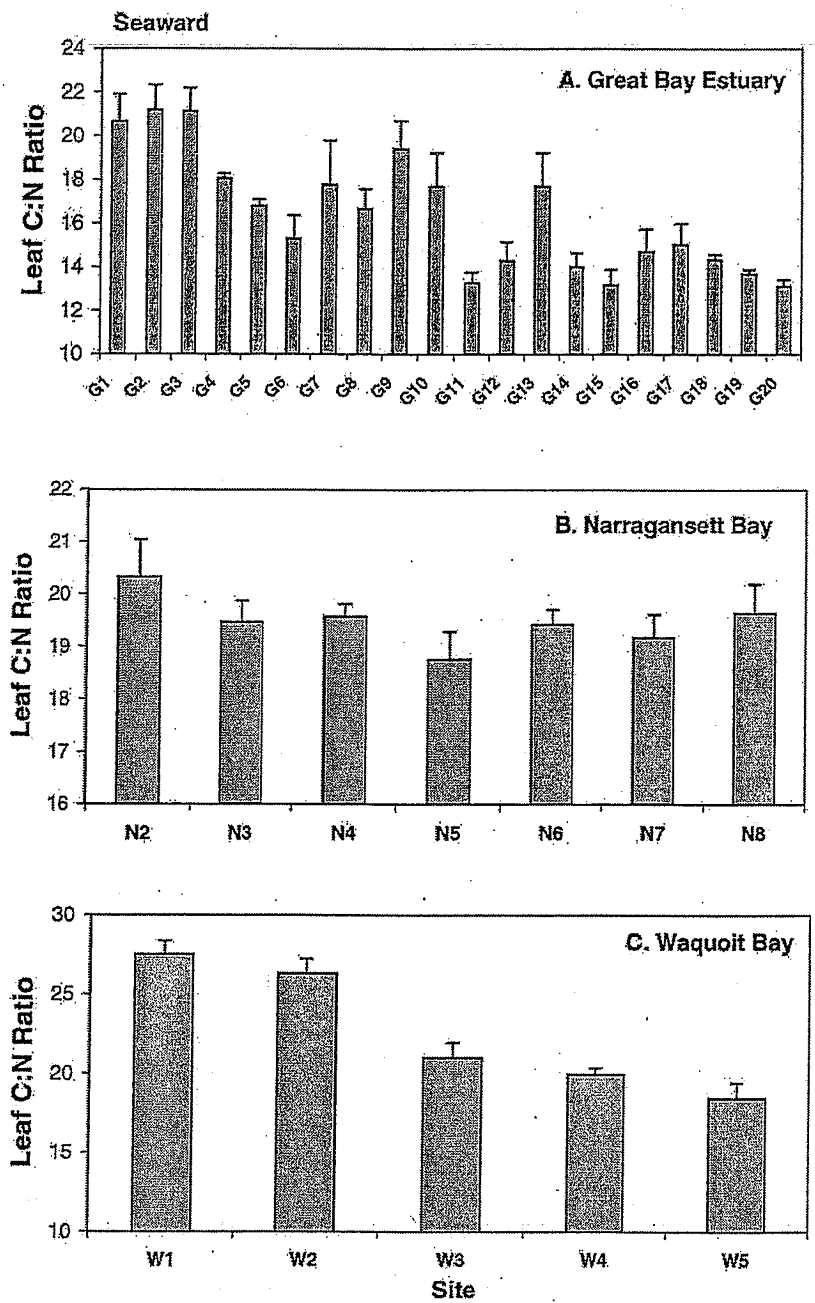

Fig. 3. Ratios of carbon to nitrogen content of eelgrass leaves along estuarine gradients in Great Bay Estuary (A), Narragansett Bay (B), and Waquoit Bay (C).

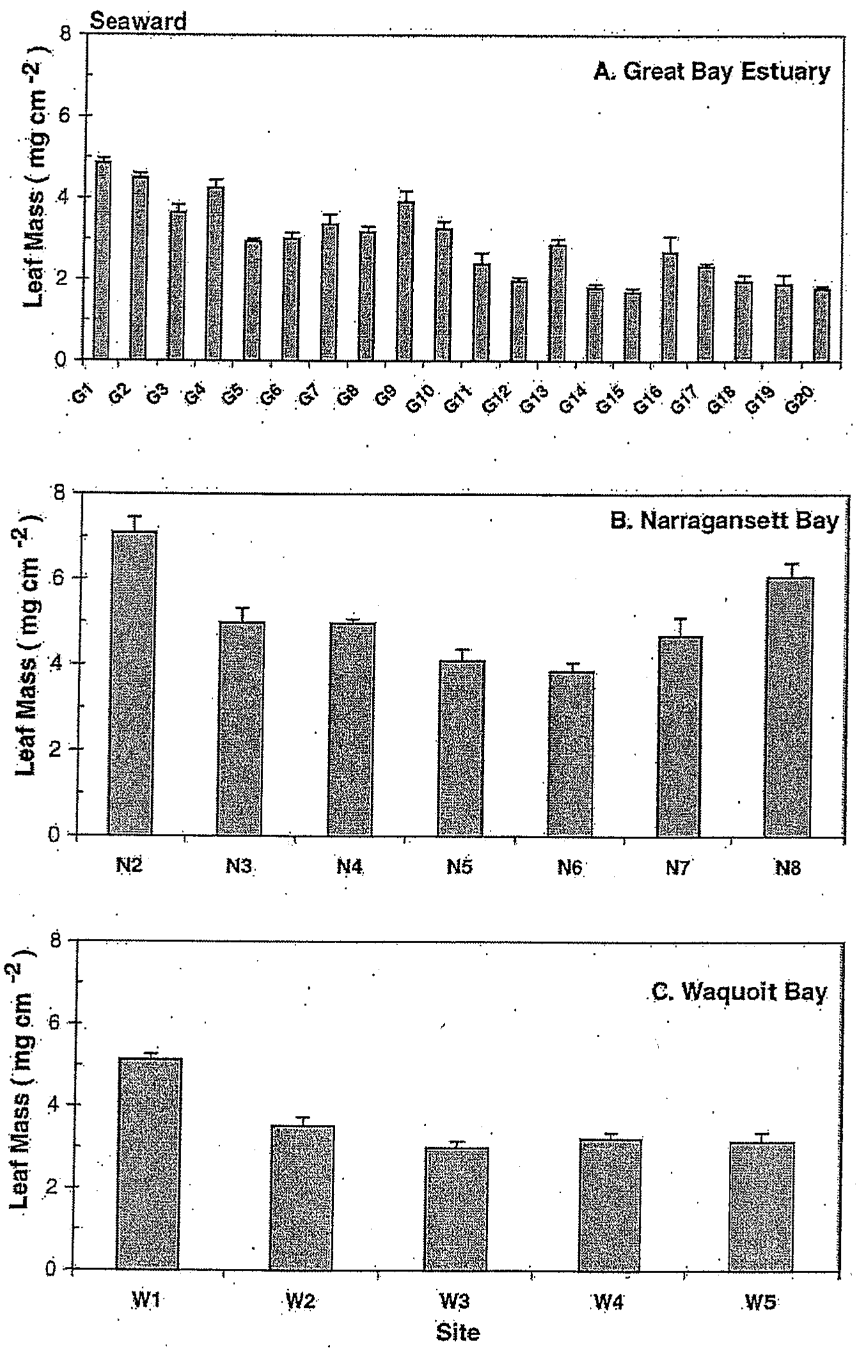

Fig. 4. Leaf mass from the mouth of the estuary to up-estuary in Great Bay Estuary (A), Narragansett Bay (B), and Waquoit Bay (C).

Table 1
Morphological parameters, epiphytes, Wasting Index and leaf tissue nutrient content of *Zostera marina* along nutrient gradients in Great Bay Estuary, Narragansett Bay and Waquoit Bay

Site	No. of leaves (Leaves shoot^{-1})	Sheath length (cm)	Shoot height (cm)	Leaf width (mm)	Epiphytes (mg cm^{-2})	Wasting Index (%)	Leaf C content (%)
Great Bay							
G1	4.5 ± 0.2	14.4 ± 1.0	59.9 ± 3.9	4.3 ± 0.2	0.013	1.6 ± 0.5	38.3 ± 0.4
G2	4.2 ± 0.2	28.2 ± 1.6	113.1 ± 7.8	4.8 ± 0.1		10.2 ± 1.9	37.9 ± 0.3
G3	3.9 ± 0.3	17.4 ± 1.3	78.1 ± 5.1	4.5 ± 0.1	0.013	10.4 ± 2.6	38.6 ± 0.2
G4	4.6 ± 0.2	23.2 ± 1.9	106.5 ± 8.3	5.7 ± 0.2	0.003	15.1 ± 2.9	37.1 ± 0.4
G5	4.6 ± 0.2	16.7 ± 1.1	75.3 ± 5.4	4.6 ± 0.2	0.010	6.6 ± 1.5	38.7 ± 0.9
G6	4.5 ± 0.2	19.5 ± 0.7	90.6 ± 3.4	5.8 ± 0.1	0.679	7.7 ± 2.4	36.4 ± 0.2
G7	3.9 ± 0.2	17.5 ± 2.1	73.6 ± 9.5	4.2 ± 0.3	0.004	9.1 ± 2.5	37.8 ± 0.5
G8	4.6 ± 0.3	15.0 ± 1.9	76.8 ± 9.9	4.1 ± 0.2	0.192	6.7 ± 2.8	38.1 ± 0.2
G9	3.5 ± 0.2	11.6 ± 0.9	46.2 ± 4.4	3.4 ± 0.2	0.165	4.9 ± 1.9	38.5 ± 0.3
G10	3.5 ± 0.2	12.6 ± 0.7	58.6 ± 4.9	4.5 ± 0.2	0.008	1.0 ± 0.4	36.7 ± 0.2
G11	4.6 ± 0.2	15.5 ± 1.0	80.2 ± 4.7	4.9 ± 0.2	0.066	0.3 ± 0.3	37.8 ± 0.2
G12	3.1 ± 0.4	17.8 ± 1.1	72.8 ± 5.6	4.3 ± 0.2	0.009	6.2 ± 0.9	37.2 ± 0.0
G13	3.9 ± 0.2	15.2 ± 2.3	64.1 ± 9.6	3.8 ± 0.3	0.580	1.7 ± 1.5	36.7 ± 0.2
G14	4.7 ± 0.3	12.0 ± 0.8	58.6 ± 3.7	4.4 ± 0.3	0.017	5.4 ± 1.7	39.2 ± 0.4
G15	4.0 ± 0.3	14.2 ± 1.0	69.8 ± 6.8	3.9 ± 0.2	0.355	3.8 ± 1.0	38.8 ± 0.9
G16	4.3 ± 0.2	20.7 ± 0.8	86.3 ± 4.5	3.8 ± 0.1	0.013	1.5 ± 0.5	37.5 ± 0.3
G17	4.9 ± 0.1	18.6 ± 1.3	87.0 ± 6.1	4.8 ± 0.2	0.016	1.2 ± 0.6	37.9 ± 0.5
G18	4.5 ± 0.2	13.9 ± 0.6	66.7 ± 4.9	4.3 ± 0.2	0.035	0.7 ± 0.3	37.8 ± 0.4
G19	3.8 ± 0.2	15.3 ± 1.3	79.3 ± 6.7	4.2 ± 0.1	0.007	1.3 ± 0.8	37.6 ± 0.8
G20	4.1 ± 0.2	9.8 ± 0.5	50.5 ± 3.7	4.2 ± 0.2	0.000	10.5 ± 2.9	38.7 ± 0.2
Narragansett Bay							
N2	3.3 ± 0.2	22.9 ± 2.5	112.0 ± 5.3	3.7 ± 0.2	0.031		34.7 ± 0.3
N3	3.3 ± 0.2	22.0 ± 1.3	74.3 ± 3.3	5.2 ± 0.2	1.285		35.2 ± 0.3
N4	2.7 ± 0.2	21.5 ± 1.0	84.0 ± 5.5	4.7 ± 0.2	0.567		34.8 ± 0.1
N5	3.1 ± 0.2	12.7 ± 1.4	54.7 ± 4.5	4.4 ± 0.2	0.292		35.7 ± 0.2
N6	2.9 ± 0.2	13.3 ± 0.9	63.7 ± 2.8	4.4 ± 0.2	0.124		36.1 ± 0.1
N7	3.3 ± 0.2	14.1 ± 1.5	71.2 ± 7.3	4.3 ± 0.2			36.1 ± 0.3
N8	2.7 ± 0.2	8.9 ± 0.9	36.4 ± 3.7	3.0 ± 0.1	1.266		36.1 ± 0.2
Waqouit Bay							
W1	3.9 ± 0.2		63.8 ± 4.6	4.3 ± 0.1	0.000		37.8 ± 0.1
W2	4.0 ± 0.0		49.0 ± 4.4	4.9 ± 0.2	0.000		38.2 ± 0.2
W3	4.2 ± 0.3		48.2 ± 2.6	5.3 ± 0.4	0.007		37.2 ± 0.2
W4	4.2 ± 0.3		78.0 ± 3.8	4.7 ± 0.2	0.035		38.4 ± 0.2
W5	4.2 ± 0.3		31.6 ± 2.0	4.8 ± 0.3	0.052		37.4 ± 0.3

Values are mean ± S.E.

Number of leaves per shoot was significantly ($P < 0.001$) different among sampling stations in Great Bay Estuary, but there was no trend along the estuarine gradient (Table 1). Numbers of leaves per shoot were not significantly different among the sampling stations in either Narragansett Bay or Waquoit Bay ($P = 0.06$ and 0.77, respectively; Table 1). Mean leaf number per shoot was lowest in Narragansett Bay (3.0), and was not significantly different between Great Bay Estuary (4.2) and Waquoit Bay (4.1; Table 1). Sheath lengths were significantly ($P < 0.001$) longer in down-estuary than up-estuary stations in both

Great Bay Estuary and Narragansett Bay, and were not significantly ($P = 0.58$) different between these two estuaries (Table 1). Sheath lengths were not measured in Waquoit Bay. Shoot heights varied throughout Great Bay Estuary, with no clear pattern along the gradient (Table 1), although taller plants were associated with deeper water. In Narragansett Bay, shoot height was greatest at the mouth of the estuary and least in the upper estuary. In Waquoit Bay, shoots were significantly ($P < 0.001$) shorter at the mouth of the estuary. Shoot heights varied in the three estuaries: the plants were significantly taller in Great Bay Estuary (74.7 cm) and Narragansett Bay (70.9 cm) than in Waquoit Bay (54.1 cm; Table 1).

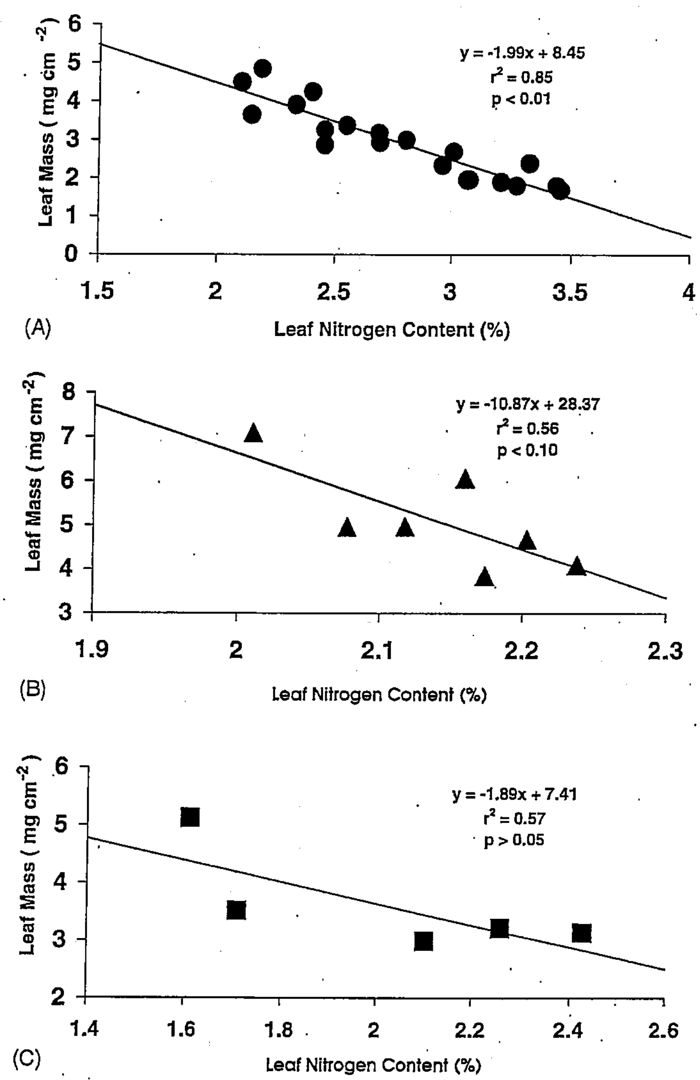

Fig. 5. Relationships between leaf nitrogen content and leaf mass in Great Bay Estuary (A), Narragansett Bay (B), and Waquoit Bay (C).

Leaf widths varied significantly ($P < 0.001$) between stations in Great Bay Estuary and between stations in Narragansett Bay but were not significantly different ($P = 0.07$) in Waquoit Bay. Leaves were significantly ($P < 0.01$) wider in Waquoit Bay (4.8 mm) than in the Great Bay Estuary (4.4 mm) and Narragansett Bay (4.2 mm; Table 1). Leaf widths showed no significant trends within each estuarine system.

3.3. Epiphytes and Wasting Index

Epiphyte biomass did not show any clear trends along the estuarine gradient in Great Bay Estuary or Narragansett Bay. In Waquoit Bay, eelgrass leaves had more epiphytes up-estuary than seaward (Table 1). Mean epiphyte biomass was highest in Narragansett Bay (0.59 mg cm^{-2} leaf area) and lowest in Waquoit Bay (0.02 mg cm^{-2} leaf area; Table 1).

The extent of the wasting disease on eelgrass shoots was assessed using the Wasting Index (Burdick et al., 1993) for Great Bay only because very low levels of wasting disease were observed in Waquoit and Narragansett Bays during the study. Wasting Index in Great Bay Estuary was significantly ($P < 0.001$) higher in seaward than in up-estuary stations, although stations 1 and 21 were exceptions (Table 1).

3.4. Relationships between leaf N content and plant characteristics

Eelgrass leaf N content exhibited negative relationships with leaf mass in all three estuarine systems (Fig. 5). Slopes of regression lines for these two parameters were similar for Great Bay Estuary and Waquoit Bay, but the slope was steeper for Narragansett Bay. The correlation between tissue N content and leaf mass was significant when values of the three estuaries were combined (Fig. 6).

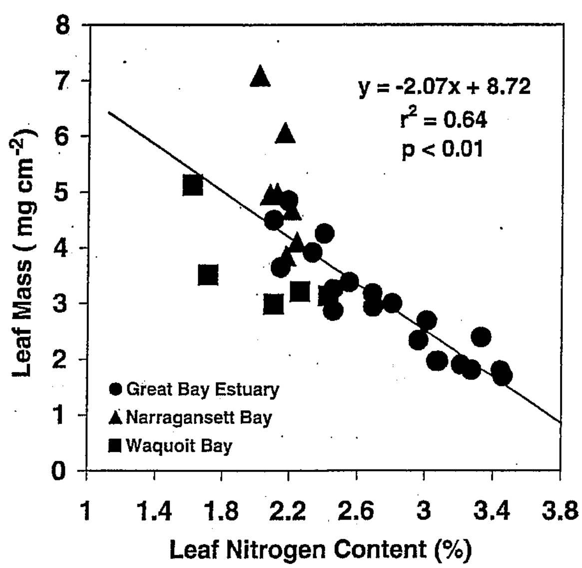

Fig. 6. Relationship between leaf nitrogen content and leaf mass for the three estuarine systems.

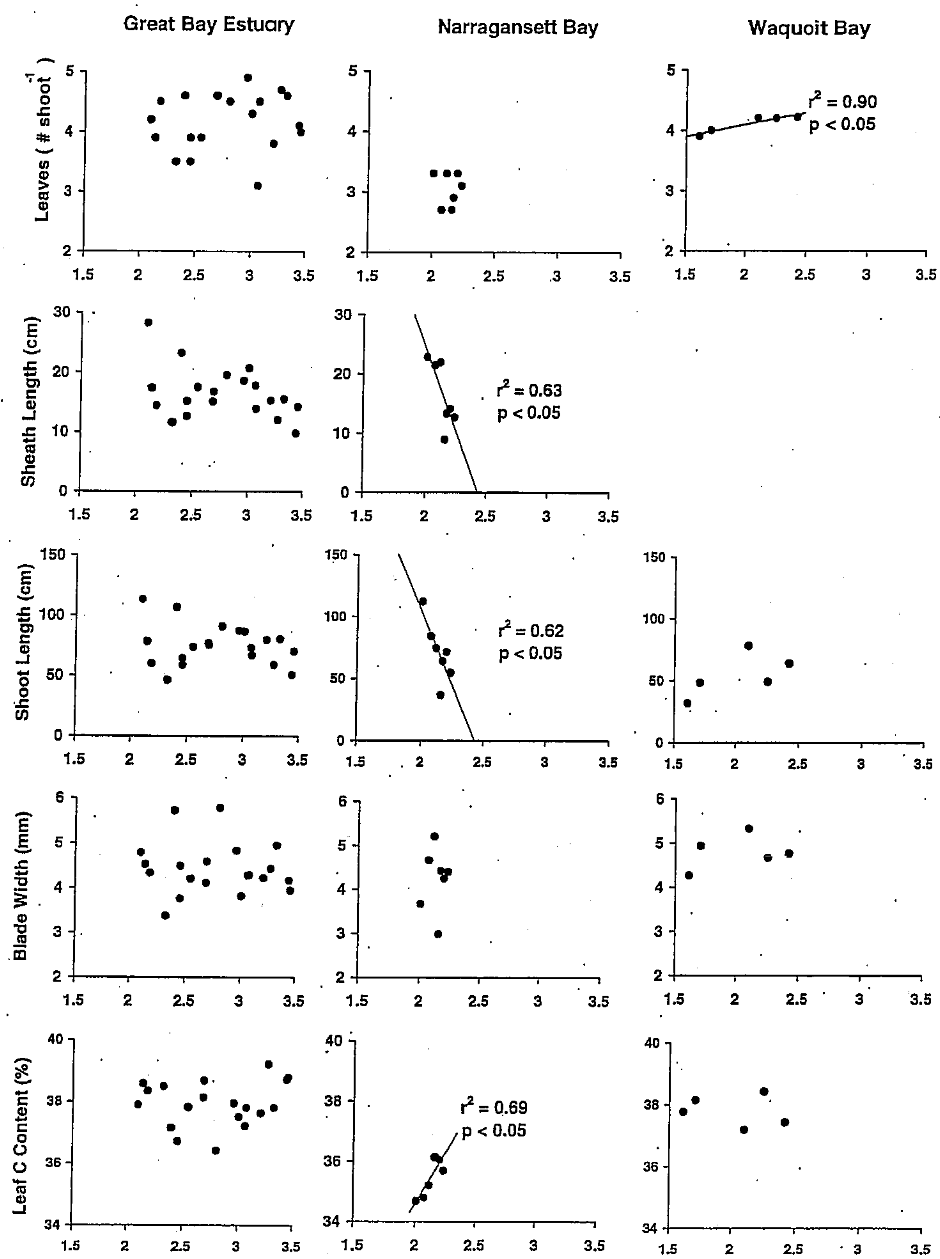

Fig. 7. Leaf nitrogen content vs. morphological parameters, leaf carbon content, epiphyte biomass, and Wasting Index in Great Bay Estuary, Narragansett Bay, and Waquoit Bay.

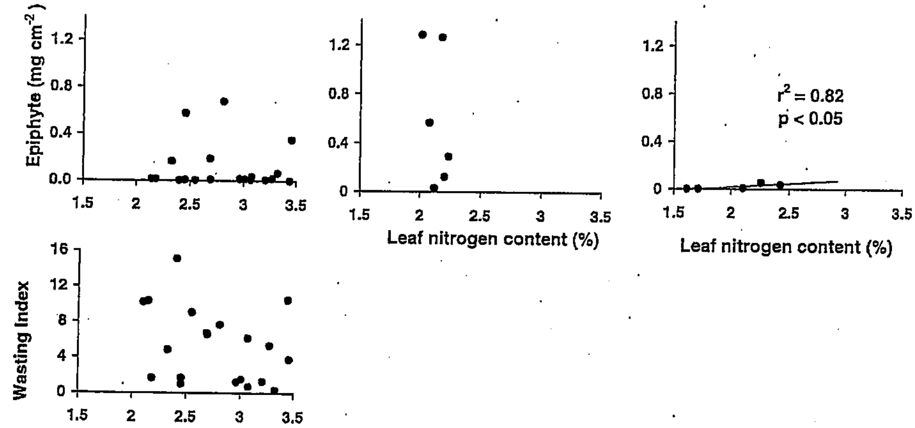

Fig. 7. (*Continued*).

In Great Bay Estuary, leaf N content did not significantly correlate with any other plant morphological characteristic, with epiphyte biomass, nor with Wasting Index (Fig. 7). In Narragansett Bay, leaf N content negatively correlated with sheath length and shoot height and positively correlated with leaf tissue C content (Fig. 7). Leaf tissue N content showed positive correlations with number of leaves per shoot and epiphyte biomass in Waquoit Bay (Fig. 7).

3.5. Ratios of leaf N content to leaf mass

Mean ratios of eelgrass leaf N content to leaf mass (NPI) ranged from 0.4 to 2.2 in the Great Bay Estuary, and were significantly ($P < 0.001$) higher up-estuary than seaward (Fig. 8A). In Narragansett Bay, the mean ratios varied from 0.3 to 0.6, and also showed significant differences ($P < 0.001$) among sampling stations (Fig. 8B). The mean ratios in Waquoit Bay, which ranged from 0.3 to 0.8, were lowest at the seaward station (W1) and were significantly ($P < 0.001$) higher in the upper parts of the estuary (Fig. 8C).

4. Discussion

Dissolved inorganic nutrient concentrations in the water column can be measured directly, but such measures represent only the instantaneous nutrient status after rapid uptake by primary producers and dilution. The nutrient content of marine plants responds to the nutrient availability and motion of the surrounding waters (Fonseca and Kenworthy, 1987; Carpenter et al., 1991; Fong et al., 1994b; Hurd et al., 1996; Stevens and Hurd, 1997). Marine plant tissue nutrient content has thus been suggested as an indicator of environmental nutrient history (Atkinson and Smith, 1983; Duarte, 1990; Short et al., 1990; Fong et al., 1994a; Fourqurean et al., 1997). To derive a robust indicator of nutrient overenrichment, we conducted a space-for-time substitution using nutrient gradients to evaluate eelgrass response to nitrogen availability in three estuaries.

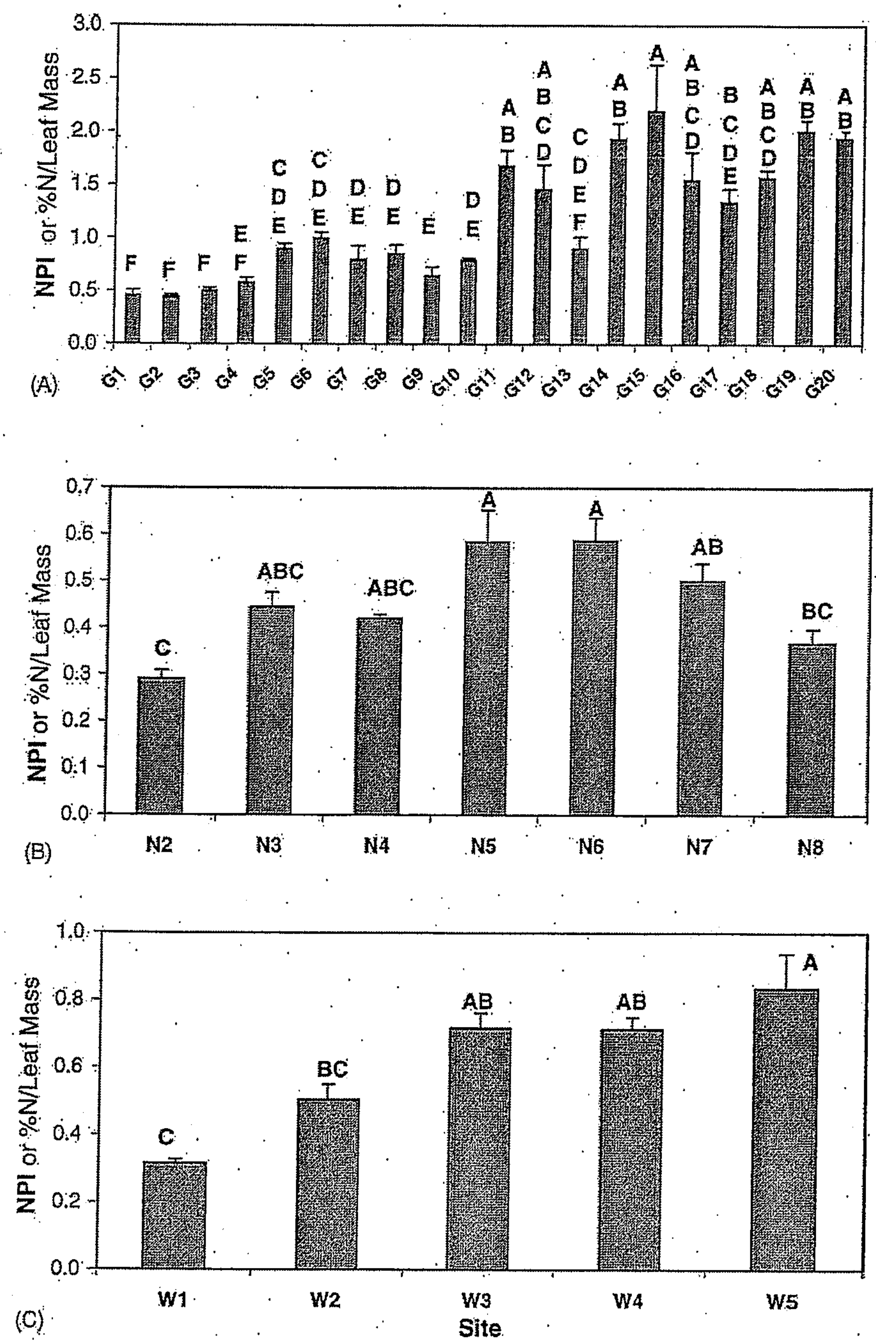

Fig. 8. The Nutrient Pollution Indicator (NPI), defined as the ratio of leaf nitrogen content (% N) to leaf mass, along nutrient gradients in Great Bay Estuary (A), Narragansett Bay (B), and Waquoit Bay (C). Values with same letter (listed above each bar) are not significantly ($P < 0.05$) different among sampling stations.

For eelgrass, we found leaf N content provides an integrated measure of environmental nitrogen experienced by the plants. Unfortunately, similar to previous investigation (Fourqurean et al., 1997), we found that eelgrass N content alone was often too variable to clearly demonstrate significant differences in nitrogen availability. Eelgrass morphological characteristics such as number of leaves per shoot, blade width, sheath length and shoot height correlated only weakly with eelgrass leaf tissue N content, and these relationships of plant morphology to N content were not consistent for the three estuarine systems (Fig. 7). After analyzing many plant characteristics, a second variable, leaf mass (area normalized, i.e., weight of leaf tissue per unit leaf area), was found to vary consistently with changes in nitrogen availability across a range of enrichment, and the relationship was significant when values of the three estuaries were combined (Fig. 6). Further, its response was highly correlated to, and inverse to, that of eelgrass leaf N content; as nitrogen available to the plants increased, leaf mass decreased.

We found that leaf N content alone could not significantly separate sampling stations located along the nitrogen gradient in Narragansett Bay (Fig. 2B), but ratios of leaf N content to leaf mass were significantly different along the gradient (Fig. 8B). In Great Bay Estuary, the highest leaf N content (3.5%) was 1.7-fold greater than the lowest (2.1%), but the highest ratio of leaf N content to leaf mass (2.2) was 5.5-fold that of the lowest ratio (0.4). These differences in scale between measures of leaf N content alone and ratios of leaf N content to leaf mass indicate the greater sensitivity of the ratio to changes in environmental nitrogen. By combining leaf N content and leaf mass in a ratio (leaf N (%):leaf mass), changes in both plant nitrogen chemistry and plant morphology are captured by the NPI.

Because seagrasses can take up inorganic nitrogen from both the sediment and the water column (Iizumi and Hattori, 1982; Thursby and Harlin, 1982, 1984; Short and McRoy, 1984; Stapel et al., 1996; Pedersen et al., 1997; Terrados and Williams, 1997; Lee and Dunton, 1999b), eelgrass leaf N content reflects the nitrogen availability in both, which are not separated by using rooted plants for the NPI. Although the NPI is useful as applied here for detecting changes in nutrient gradients within an estuarine system, testing of hydroponically deployed eelgrass is necessary for direct comparison between estuaries (Lee et al., in preparation).

Primary producers compete for inorganic nutrients in the water column (Fong et al., 1994b). Since phytoplankton (in the water column) and epiphytes (on the seagrass blade surface) encounter nutrients released to the water before these nutrients reach seagrasses, they out-compete seagrasses for nutrients (Short et al., 1995). Excessive nutrient loading in an estuary can convert the seagrass-dominated community to a plankton-dominated or macroalgal-dominated ecosystem, or a system with excessive amounts of epiphytic algal growth on the seagrass (Short et al., 1993). Narragansett and Waquoit Bays already have converted to phytoplankton and macroalgal dominance, respectively, and have lost large amounts of their seagrass habitat (Valiela et al., 1992; Short et al., 1993). Nutrients entering Narragansett Bay and Waquoit Bay are likely taken up by various algal communities first, with eelgrass leaves exposed to the remaining nutrient concentrations. Nutrient competition among primary producers may be a cause of the lower leaf N content of eelgrass growing in Narragansett Bay and Waquoit Bay (Fig. 8B and C). Eelgrass leaf tissue N content is likely not fully representative of the nitrogen regime of estuarine systems which have large populations of phytoplankton or macroalgae, making the NPI useful primarily at early stages of overenrichment.

In conclusion, eelgrass leaf N content reflected the environmental nitrogen exposure which plants experienced. Plant morphological characteristics such as number of leaves per shoot, blade width, sheath length and shoot height showed inconsistent trends along the three estuarine gradients and correlated only weakly with eelgrass leaf N content. Leaf mass showed strong and consistent negative correlation with all three nitrogen gradients and with eelgrass leaf N content, suggesting that leaf mass also reflects environmental nitrogen. The ratio of eelgrass leaf N content to leaf mass (NPI) provides a robust and sensitive early indicator of overenrichment. Further testing of the NPI will evaluate temporal differences and relate the indicator to absolute nutrient exposures.

Acknowledgements

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ATTACHMENT H

Project Narrative Statement (Workplan)

EPA Regional Dedicated Water Quality Program
Funding Announcement # EPA-R1-07-CWQ-01

Program: Water Quality Standards Program Development

Project Title: "Using Moored Arrays and Hyperspectral Aerial Imagery to Develop Nutrient Criteria for New Hampshire's Estuaries"

Funding Amount : $70,000

Principal Investigators

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Jennifer Hunter of the New Hampshire Estuaries Project will be the lead PI for the project. Resumes for all the PIs are provided at the end of this narrative.

Environmental Results

This project will benefit the environment by establishing numeric nutrient criteria for New Hampshire's estuaries which protect eelgrass habitat.

Project Description

A. General Summary Statement of Project Goal & Justification

Increasing nitrogen concentrations (Figure 1) and declining eelgrass beds in Great Bay (Figure 2) are clear indicators of impending problems for NH's estuaries (NHEP, 2006). The NH Department of Environmental Services (DES) is responsible for developing nutrient criteria for NH's estuaries. DES, in collaboration with the New Hampshire Estuaries Project (NHEP), began this process with the formation of a workgroup in 2005. The NHEP Coastal Scientist, a DES employee, is coordinating the work to undertake this process, with input from the workgroup. Information from the workgroup meetings is available at www.nhep.unh.edu/programs/nutrient.htm. This workgroup adopted eelgrass survival as the water quality target for nutrient criteria development for NH's estuaries.

Eelgrass survival is largely dependent on light availability. The NHEP Coastal Scientist has undertaken a review of the water clarity data for NH's estuaries. There are three important constituents in the optically complex coastal waters: phytoplankton, non-algal particulates, and colored dissolved organic matter (CDOM, IOCCG 2000). These constituents, by changing the Inherent Optical Properties (IOPS), affect water clarity or more precisely the magnitude of light attenuation, an Apparent Optical Property (AOP, see Mobley, 1994). Preliminary results indicate that CDOM is the major factor controlling water clarity. However, NHEP is not able to draw strong conclusions from these results because of significant datagaps and a large degree of spatial heterogeneity in NH's estuaries.

Therefore, the NHEP is seeking funding to support an instrumented buoy in Great Bay, which will be managed by the University of New Hampshire (UNH) Coastal Observing Center, to gather sufficient data to resolve uncertainties in relationships between parameters. Funding will also support coordinated collection of spatial data from aerial imagery and flow-through surveys to characterize spatial heterogeneity in water quality parameters. The goal of the research is to develop a scientifically defensible conceptual model of the relationships between water clarity and water quality parameters. The conceptual model will be the basis of nutrient criteria for NH's estuaries. A secondary goal of the project is to demonstrate the value of integrating buoy-based measurements with aerial imagery and flow-through surveys to map heterogeneity in water quality parameters within estuarine and near-coastal systems.

Figure 1: Dissolved inorganic nitrogen concentrations in Great Bay (NHEP, 2006)

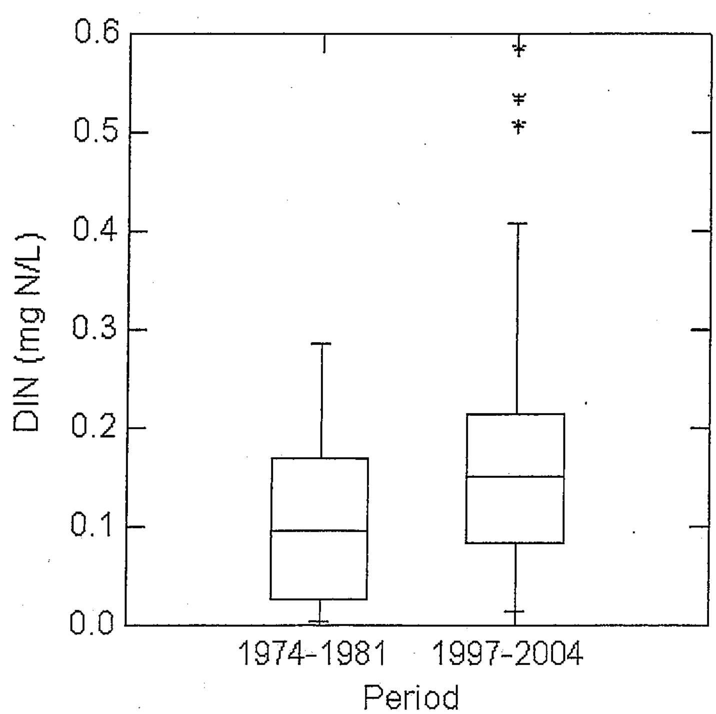
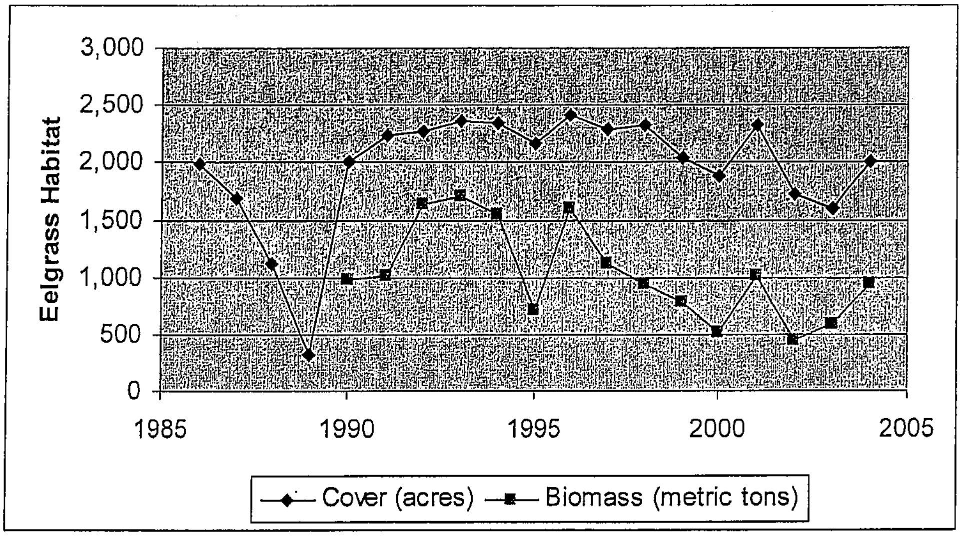


Figure 2: Eelgrass cover and biomass in Great Bay (NHEP, 2006)



<u>B. Plan for Tracking and Measuring Progress Towards Achieving the Expected Project Outputs and Outcomes</u>

The expected outputs for this project are results of research which supports development of environmental results-based nutrient criteria for estuaries, specifically:

A) A single or multi-variate model between the light attenuation coefficient and concentrations of CDOM, turbidity/suspended solids, and chlorophyll-a for the Great Bay system which can be used to develop numeric nutrient criteria;
B) Maps of the distribution of CDOM, turbidity, and chlorophyll-a (and light attenuation using the model described above) on at least two different days for the entire Great Bay system; and
C) A calibrated light availability model for the Great Bay system.

All three of the outputs will support the expected outcome of developing numeric nutrient criteria for water clarity and, therefore, the protection of eelgrass beds. Eelgrass is a critical estuarine habitat. The protection of this habitat would benefit all users of the estuary: fish, waterfowl, and humans.

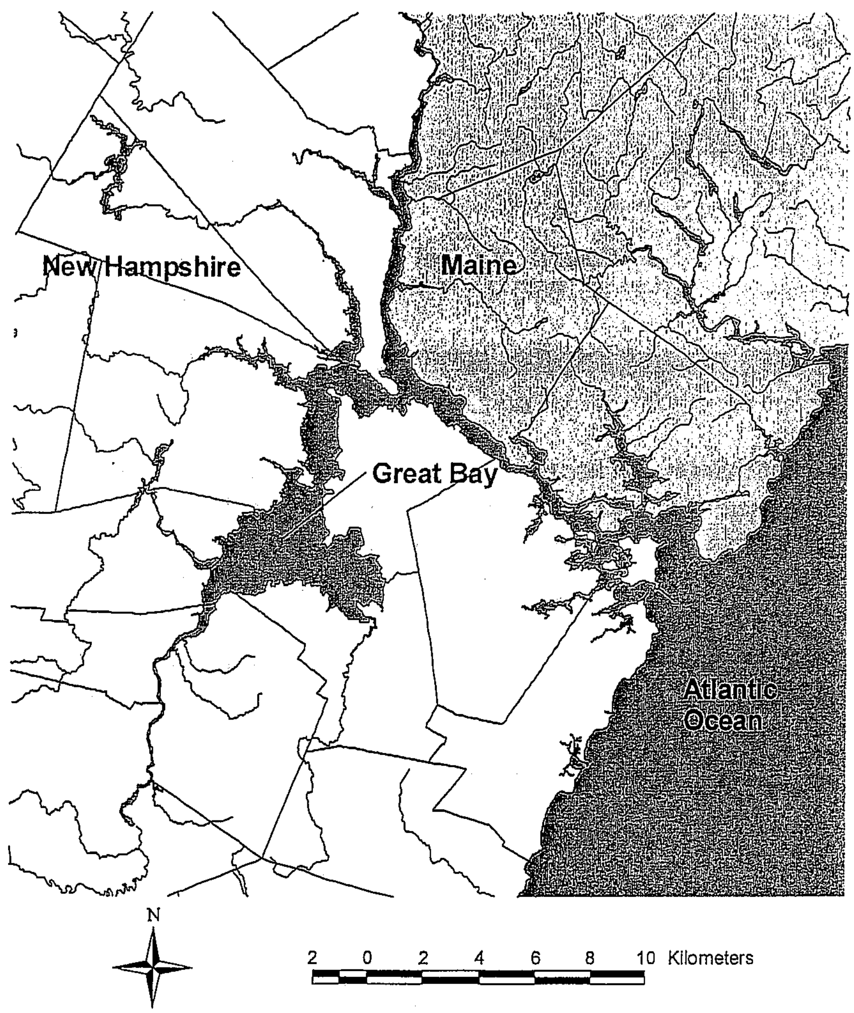
Presentations of the plans for the studies and the results of the research will be made to the NHEP Technical Advisory Committee, which is serving as the advisory group to DES on the process of developing nutrient criteria.

Progress toward achieving these outputs will be documented in one interim and one final report to EPA. The desired outcome will be achieved when NHEP makes a recommendation to the Water Quality Standards Advisory Committee for a water clarity based water quality criterion for NH's estuaries.

C. Project Description

The project will be completed in the Great Bay estuarine system of NH and Maine. This area encompasses the Great Bay, Little Bay, Piscataqua River and some or all of the tidal portions of the Winnicut, Squamscott, Lamprey, Oyster, Bellamy, Cocheco and Salmon Falls Rivers (Figure 3). Approximately 40 square kilometers of estuarine waters will be part of the study area.

Figure 3: The Great Bay Estuary



The project will be completed by a partnership of the New Hampshire Estuaries Project, the NH Department of Environmental Services, and the University of New Hampshire.

The NHEP is part of EPA's National Estuary Program, and is coordinating the nutrient criteria development process through its Technical Advisory Committee, with the NHEP Coastal Scientist leading the work. The NHEP's latest "State of the Estuaries" report highlighted declines in eelgrass beds and increases in nitrogen concentrations in Great Bay (available at www.nhep.unh.edu).

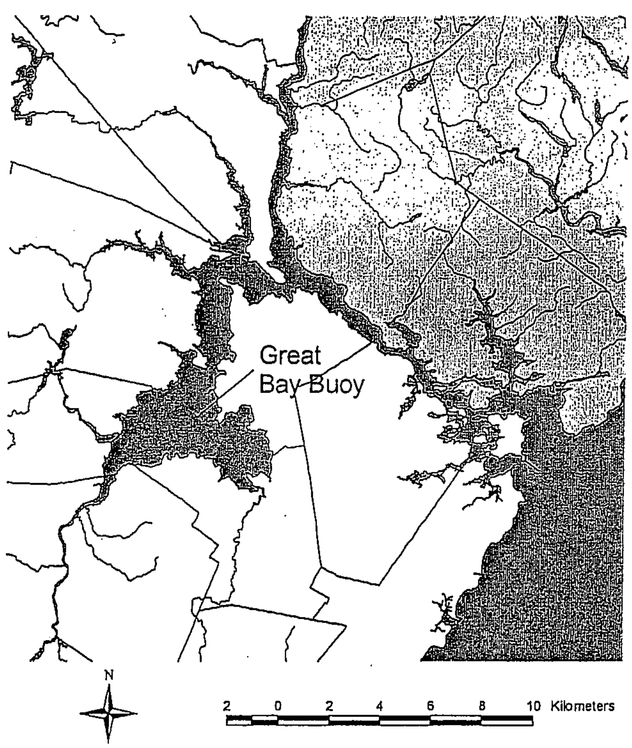
DES is responsible for developing nutrient criteria in NH's estuaries and has completed the initial evaluation of water clarity data (available at www.nhep.unh.edu/programs/nutrient.htm).

The UNH Coastal Observing Center, an IOOS pilot project funded through the NOAA Coastal Services Center, has deployed an instrumented buoy in Great Bay in 2005 and 2006. This group also conducts periodic cruises throughout the Great Bay system with flow-through instrument array to document spatial heterogeneity of water quality parameters (UNH, 2005; UNH, 2006). The UNH Marine Program conducts routine monitoring of water quality at seven stations distributed throughout the estuary for the Great Bay National Estuarine Research Reserve, the NHEP, and UNH research.

The project will consist of three parts.

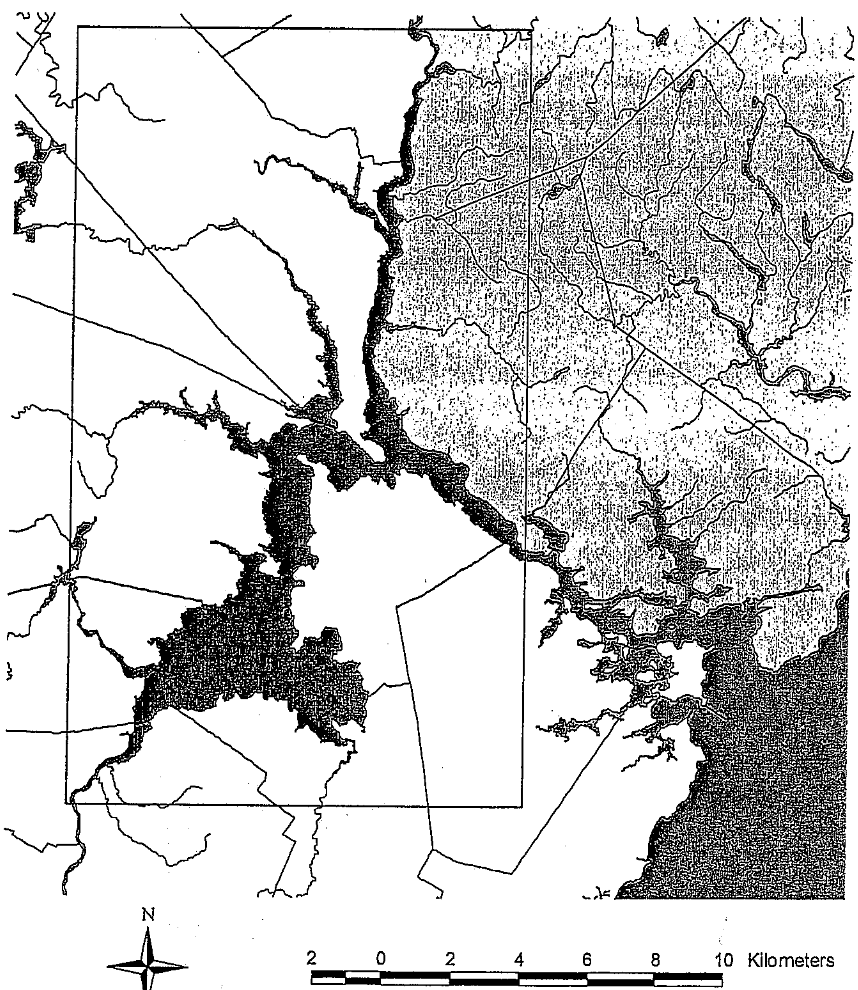
For the first task of the project, UNH Coastal Observing Center will redeploy a moored buoy in Great Bay (Figure 4) with appropriate sensors for measuring the hyperspectral light field including attenuation coefficients and the remote sensing reflectance, as well as CDOM, turbidity, chlorophyll-a, nitrate, and other physico-chemical parameters (http://www.cooa.unh.edu/buoydata/buoy.jsp). These parameters will be measured in-situ on a 30 minute time step. The large volume of data on all the parameters related to light attenuation, collected over a broad range of environmental and optical conditions, will make it possible to derive a statistically significant relationship to predict water clarity from water quality parameters (Output A).

Figure 4: Buoy and sampling locations within the Great Bay Estuary



For the second task of the project, the NHEP will arrange for at least two overflights to collect hyperspectral imagery of the entire Great Bay system. The overflights will be conducted by SpecTIR (www.SpecTIR.com). SpecTIR proposes an airborne data collection with the VNIR sensor with a spatial resolution of 2.5 meters for the area of interest (Figure 5, in red), and a nominal spectral resolution of 10nm or 64 spectral channels from approximately 430 nm to 1000 nm. The delivered product will consist of calibrated radiance and geographic lookup tables with navigation. Navigation will be performed with high speed airborne DGPS integrated with a laser ring gyro. Personnel in the company have more than 10 years in the planning of hyperspectral flights and the collection/processing of airborne hyperspectral data. Specifications for the SpecTIR VNIR sensor are appended to this workplan.

Figure 5: Area for hyperspectral imagery collection (shown in red)



The overflights will be coordinated with times of buoy operation, grab sample collection and flow-through surveys to ground truth the imagery. Field sampling and buoy operation will be completed by the UNH Coastal Observing Center and the UNH Marine Program. The flow-through transects will continuously measure water temperature, salinity, chlorophyll-a, and colored dissolved organic matter. Grab samples will be analyzed for physico-chemical parameters, dissolved nutrients, total nutrients, chlorophyll-a, total suspended solids, CDOM, and water clarity (measured in the field). A custom profiling package will measure the vertical distribution of the IOPs with a hyperspectral attenuation-absorption meter and nine channel backscattering meter (ACS and BB-9 WetLABS Inc). Laboratory based measurements of absorption spectra for the optically important constituents from discrete water samples will help with the interpretation and validation of profiler measurements (Mitchell et al, 2000). At six stations (Figure 4), the UNH Marine Program operates in-situ datasondes deployed on buoys which measure temperature, salinity, dissolved oxygen, pH and turbidity on a 30 minute time step. The combination of in-situ moored measurements, flow-through measurements, and grab samples will be used to ground truth the aerial imagery.

After calibrating the hyperspectral imagery with the ground truth measurements, the UNH Coastal Observing Center will analyze the imagery to map the distributions of chlorophyll-a, CDOM, particulates, and benthic light availability throughout the system (Output B). The combination of aerial imagery and ground truth measurements has been proven to be effective at producing accurate maps of water quality parameters (Sugumaran et al., 2005) and submerged aquatic vegetation (Dierssen et al, 2003).

For the third task of the study, UNH Coastal Observing Center will apply a multi-spectral radiative transfer model (Hydrolight, Sequoia Inc.) to the Great Bay to predict light availability to eelgrass under different water quality conditions. The model will be customized to Great Bay conditions using the information from the first part of the study. By comparing the model output to the measured light availability, UNH will be able to verify consistency with optical theory (Output C).

Finally, this project has been designed to meet many of the aims and goals of the Integrated Ocean Observing System (IOOS) by facilitating the use of observing system measurements by those involved in managing the state's coastal water. Funding for the initial development and deployment of the Great Bay Coastal Buoy was derived from an IOOS pilot project from the NOAA Coastal Services Center to the Coastal Observing Center at UNH.

No human subjects or research animals will be used for this study.

D. Deliverables and Schedule

1. Prepare quality assurance project plan – due one month after receipt of award.
This report will document the methods to be used for the study and the quality assurance procedures. The plan will be approved by project partners and EPA Region I.

2. Purchase sensor equipment and deploy buoy – due by 7/15/07
UNH Coastal Observing Center will purchase, with separate funds, a junction box and other equipment needed to measure hyperspectral light intensity at two depths in the water and one location in the air. The buoy will be deployed in the middle of Great Bay at approximately 43.0715 degrees N latitude and 70.8677 degrees W longitude (Figure 4).

3. Obtain hyperspectral aerial imagery – due by 10/31/07
SpecTIR will obtain hyperspectral band imagery for the study area on two different dates between 7/15/07 and 10/31/07.

4. Collect water quality data from flow-through surveys and grab samples – due by 10/31/07
UNH Coastal Observing Center will measure water quality parameters along transects using a flow-through sampling device on the same date as the hyperspectral aerial imagery. UNH Marine Program will collect grab samples for water quality parameters at seven stations and operate six in-situ datasondes on the same date as well (Figure 4). These data will be used for ground truthing the aerial imagery.

5. Present preliminary results to nutrient criteria work group – due by 12/31/07
NHEP will present the preliminary results of the project to the nutrient criteria workgroup during the fall of 2007. The group will provide feedback on the results and guidance for additional analysis.

6. Interim status report – due 12/31/07
The NHEP will prepare a report to EPA on the status of the project. The interim status report will summarize the field data collection activities that occurred in 2007 and will note any discrepancies from the QAPP.

7. Final report – due 6/30/08
The final report will contain the planned outputs for the project (listed below), conclusions and recommendations.

Planned Outputs

A) A single or multi-variate model between the light attenuation coefficient and concentrations of CDOM, turbidity/suspended solids, and chlorophyll-a for the Great Bay system which can be used to develop numeric nutrient criteria;

B) Maps of the distribution of CDOM, turbidity, and chlorophyll-a (and light attenuation using the model described above) on at least two different days for the entire Great Bay system; and

C) A calibrated light availability model for the Great Bay system.

8. Present results to nutrient criteria work group – due by 6/30/08
NHEP will present the results of the project to the nutrient criteria workgroup during the spring of 2008.

9. Recommendation to the Water Quality Standards Advisory Committee – due 12/31/08
The nutrient criteria workgroup (staffed by DES) will prepare a white paper to present its recommendations to the WQSAC.

<u>E. Cost</u>
The total cost of the project will be $70,000. An itemized budget is attached.

Program Capability Information

National Estuary Program Annual Assistance Agreements (2004, 2005, 2006)
Awardee: New Hampshire Estuaries Project (University of New Hampshire)
Funding Source: EPA National Estuary Program (CFDA: 66-456)
EPA Project Manager: Jean Brochi, EPA Region 1, 617-918-1536, brochi.jean@epa.gov
Project Period: New Annual Agreements each year, variable in length
Total Project Cost: Roughly $1,000,000 per year ($500,000 National Estuary Program funds and $500,000 non-federal matching funds)

Achievement of Technical Success: The NHEP is part of the EPA National Estuary Program which is a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuaries. The NHEP has a 4-person staff, plus support from the University of New Hampshire Office of Sponsored Research and Business Service Center. A 27-person Management Committee oversees the work of the NHEP, sets program priorities each year, and approves the annual workplan. The annual workplan clearly defines what activities the NHEP will undertake with available funding each year. The NHEP's Comprehensive Conservation and Management Plan for New Hampshire's estuaries was completed in 2000 and implementation is ongoing. The Management Plan outlines key issues related to management of New Hampshire's estuaries and proposes strategies that are expected to collectively preserve and protect the state's estuarine resources. As of 6/30/06, the NHEP had initiated activities for all of its 45 highest priority action plans that are part of the original Management Plan. Of these, six have been completed or fully implemented (in the case of ongoing action plans). The NHEP has also implemented a successful monitoring program which integrates environmental data from State agencies, UNH, and other organizations (NHEP, 2004). The NHEP, through its contractors, conducts annual monitoring of the water quality, shellfish resources, eelgrass habitat and land use in the coastal watershed. Each year the NHEP manages about $60,000 to $70,000 worth of contractual work related to estuarine monitoring. The NHEP develops work scopes and budgets for all monitoring work, manages subcontracts, and manages data that are collected through these efforts. In addition to monitoring, the NHEP conducts activities and manages contractors' work in the areas of habitat protection, restoration, water quality improvements, and community outreach.

Fulfillment of Reporting Requirements: Reporting is completed by the NHEP in a number of ways:

- The NHEP is required to prepare an annual workplan for the EPA award. In this document, the NHEP reports on the activities completed in the previous year in fulfillment of previous work plan objectives. The NHEP has submitted workplans to EPA each year on or about June 30. See the last 3 work plans for more details:
  - Year 9 Work Plan: http://www.nhep.unh.edu/resources/pdf/nhepyearnine-nhep-04.pdf
  - Year 10 Work Plan: http://www.nhep.unh.edu/resources/pdf/nhepyearten-nhep-05.pdf
  - Year 11 Work Plan: http://www.nhep.unh.edu/resources/pdf/nhep_year_eleven-nhep-06.pdf
- The NHEP tracks implementation progress in a database that records staff activities and contractor activities related to management plan actions. The database is sent to the EPA project manager each quarter. The EPA project manager can generate quarterly and final reports for each assistance agreement from the database.

- The NHEP provides EPA with the individual final reports for all projects funded by the NHEP (e.g., subawards granted by the NHEP and activities completed by NHEP staff in fulfillment of activities identified in the annual workplans).
- As part of GPRA reporting, the NHEP reports yearly to EPA on habitat acres protected or restored; funds leveraged by the program; Management Plan implementation progress; and environmental indicators used by the program.
- Finally, every three years the NHEP submits a comprehensive implementation report to EPA as part of its triennial implementation review. (see the most recent submittal at http://www.nhep.unh.edu/resources/pdf/implementation_review-nhep-06.pdf)

National Coastal Assessment
Awardee: NH Department of Environmental Services
Funding Source: EPA Office of Research and Development
Funding Source Contact: Charlie Strobel, EPA, 401-782-3180, strobel.charles@epa.gov
Project Period: 7/1/01 – 6/30/05
Total Project Period Cost: $750,832

Achievement of Technical Success: The National Coastal Assessment was a national initiative to conduct probability-based monitoring for all estuarine waters in the United States. EPA supported a four year monitoring effort through seed funding and training. EPA developed a cooperative agreement with DES to conduct the NCA monitoring in NH. DES partnered with UNH to complete the work. UNH staff were responsible for field operations, sample handling, and laboratory analysis. DES staff were responsible for project management, data management, quality assurance and reporting. All of the required tasks for the National Coastal Assessment in NH were successfully completed. All of the data were provided to EPA promptly and have subsequently been uploaded to the DES Environmental Monitoring Database (which ultimately uploads to STORET).

Fulfillment of Reporting Requirements: The cooperative agreement required semi-annual progress reports to EPA. During the past five years, progress reports were sent to EPA on 2/13/03, 7/30/03, 2/13/04, 7/29/04, 1/24/05, 10/6/05, 3/31/06, 8/7/06, and 1/31/07. Quarterly MBE/WBE reports were filed with EPA Region I on 7/25/03, 10/22/03, 1/30/04, 4/22/04, 7/15/04, 10/15/04, 1/14/05, 4/15/05, 10/6/05, 2/10/06, 4/17/06, 8/7/06, and 2/2/07. Final technical reports were provided as follows:

- 6/30/04: Final report on intensive sediment sampling
- 1/13/05: Final report on 2000-2001 dataset
- 7/27/05: Final report on dissolved oxygen in the Squamscott and Lamprey rivers
- 3/16/07: Final report on 2002-2005 dataset

UNH Coastal Observing Center
Awardee: UNH Coastal Observing Center
Funding Source: NOAA Coastal Services Center
Funding Source Contact: Geno Olmi: phone (843) 740-1230, geno.olmi@noaa.gov
Project Period: 2002 – July 2007
Total Project Period Cost: $11,620,060

Achievement of Technical Success: The Coastal Ocean Observing Center at UNH has developed and implemented a system for monitoring the oceanic and estuarine ecosystem in the western Gulf of Maine. This monitoring system has the capability to detect changes in the ecosystem across multiple physical and trophic levels, and will enable researchers to understand, and ultimately forecast changes in the ecosystem. The system is designed to serve the information needs of fisheries and coastal resource managers, educators, and scientists. Data gathered with this system are establishing a multi-year description of the ecosystem which is not only useful to scientists, educators, and resource managers today, but will prove an invaluable reference point for researchers in the future.

Since its establishment in 2002, the Center has achieved national and regional prominence for its achievements in several areas. These include our unique and invaluable time series being generated by our monitoring program, the use of technologically advanced sensors on both buoys and sampling cruises, the development of award winning educational materials and tools, and connection to user communities through presentations, displays, news media, and publications. One of the automated sampling systems we use is a state-of-the-art buoy placed in the Great Bay between April 28 and November 30, 2005, and May 12 and December 1, 2006. Developed specifically for use in near-coastal environments, the buoy utilizes new chemical and optical sensors and wireless telemetry to monitor water properties such as turbidity, inorganic nutrients, dissolved organic carbon, chlorophyll, and other substances. Data from the buoy are transmitted hourly to our data management system, WebCOAST. Data are publicly available and presented in the context of historical data dating back to 1973. The buoy was in place to measure record low salinities associated with rainfall events in October 2005 and May 2006, gathering important data on the resulting changes in Great Bay water chemistry. This buoy is a prototype for future coastal buoys that will monitor water quality in estuaries.

Fulfillment of reporting requirements: NOAA requires semiannual progress reports and the most recent of these can be found at the documentation page of the Coastal Observing Center website http://www.cooa.unh.edu/documentation.jsp.

Environmental Results Past Performance

National Estuary Program Annual Assistance Agreements to the NHEP
(Grant information provided in previous section)
Fulfillment of Environmental Results Reporting: Every three years, the NHEP produces a Progress Report, which documents the completion status for each of the action plans in the NHEP Management Plan. The NHEP uses this report to identify priority action plans. In addition, the NHEP has developed a set of environmental indicators to track environmental results in the estuary. The indicators are presented every three years in a State of the Estuaries report (NHEP, 2006) and associated technical reports (available at http://www.nhep.unh.edu/programs/environmental-monitoring.htm). The indicators document the status and trends for water quality, shellfish resources, critical species and habitats, and land use in the study area. Finally, as described in the previous section, the annual workplans submitted by the NHEP to EPA document achievement of objectives and goals set in the previous year's work plan.

National Coastal Assessment
(Grant information provided in previous section)
Fulfillment of Environmental Results Reporting: In accordance with the QAPP, DES conducted quality assurance reviews of the data before submitting the data to EPA. The quality assurance review included a comparison of the actual data collected to the annual workplan. DES documented the quality assurance review in memos to EPA for the 2002, 2003, 2004, and 2005 datasets (dated 4/12/05, 6/11/04, 6/30/05, and 6/30/06, respectively). In addition, DES conducted an annual quality assurance self-assessment of the program as part of the DES Quality Management Program.

UNH Coastal Observing Center, specifically the Great Bay Coastal Buoy Support
(Grant information provided in previous section)
Fulfillment of Environmental Results Reporting: Progress reports submitted to NOAA contain details of successes in the development, deployment, operations and maintenance of the buoy in Great Bay. In addition, presentations at international scientific meetings have focused on the buoy design, data visualization, and most recently on the operations and maintenance as well as the quality assurance and control process. The most recent presentation at the American Society of Limnology and Oceanography Aquatic Sciences 2007 conference can be found at http://www.cooa.unh.edu/presentations/Gregory_Poster_ASLO_07_4.pdf. Additional information can is available at the UNH Coastal Observing Center's website specifically the documentation and buoy websites.
http://www.cooa.unh.edu/buoydata/buoy.jsp
http://www.cooa.unh.edu/documentation.jsp

Intergovernmental Review

The NHEP has submitted this grant application to the Single Point of Contact (SPOC) for NH (Mark Toussaint, OEP, mark.toussaint@nh.gov) in compliance with the requirements for the Intergovernmental Review process.

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